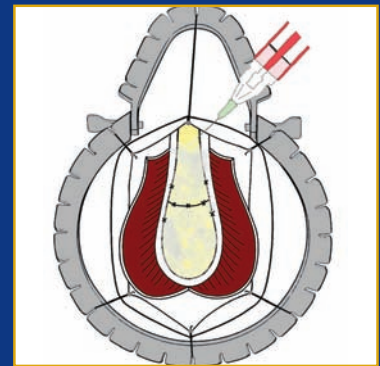
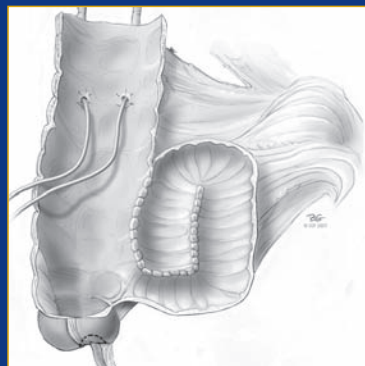
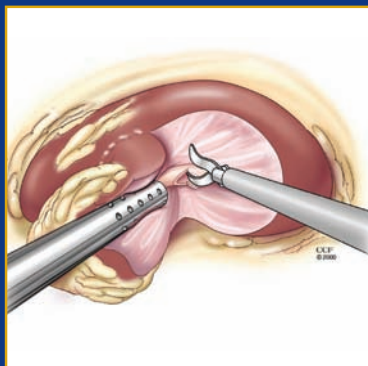
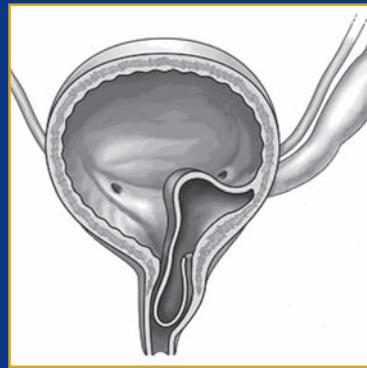
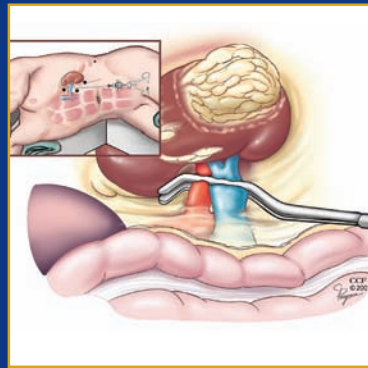


Textbook of RECONSTRUCTIVE UROLOGIC SURGERY



Edited by
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Preface

Reconstructive urology has made many advances in the past ten to fifteen years primarily as a result of significant progress in minimally invasive surgery. This is the first major text to examine adult and pediatric reconstructive procedures from the standpoint of open, laparoscopic, endourologic, microsurgical, prosthetic, tissue engineering

and robotic approaches. An internationally renowned set of contributions have graced us with their wisdom.

Drogo K. Montague

Acknowledgment

To our families who have supported us while patiently enduring our absences, to our mentors and colleagues from whom we have learned, to our residents and

fellows who give us more than we give them, and lastly, to our patients who make this all meaningful

I Modern urologic imaging

Dennis LL Cochlin

There are a number of imaging methods that can be used in the genitourinary tract. Whole texts have been written on the subject and this is but a single chapter. What follows is therefore not a comprehensive account but an overview of different imaging modalities with an indication of their use in the genitourinary system. In some cases they are alternatives to each other, while in others they complement one another. Examples are shown which include genitourinary pathology, not all of which is necessarily directly relevant to reconstructive surgery, and some are supplied simply as examples.

THE INTRAVENOUS UROGRAM

The intravenous urogram (IVU, intravenous pyelogram [IVP]) has largely been superseded in many cases by ultrasound and computed tomography (CT) or less frequently by magnetic resonance imaging (MRI).^{1,2} Nevertheless, the IVU is still in relatively widespread use. Even if this changes in the future, patients' previous investigations may be in the form of an IVU. For this reason a brief discussion of the technique follows.

The IVU consists of a plain (control or scout) film obtained before intravenous contrast is administered. This is to detect radio-opaque calculi that may not be visible on the contrasted films as they are of similar radiodensity to the contrast that fills the collecting system. Intravenous iodinated contrast is then given as a bolus injection. This is initially contained within the intravascular space but soon passes through the glomeruli into the tubules. A film taken in the first few minutes after contrast is given opacifies the renal parenchyma, the nephrographic phase. This provides an image of the renal outlines. These outlines are often poorly seen and partly obscured by overlying bowel.

After about 5 minutes the calyceal systems are filled with contrast. By 10–15 minutes the calyces, ureters, and bladder are filled, though excretion is delayed, often considerably, in an obstructed system.

The calyces are seen with varying clarity depending on how well the contrast is excreted and to what degree they are obscured by bowel contents. Only portions of the ureters are usually seen on a single film depending



Figure 1.1 Intravenous urogram (IVU). This demonstrates how an IVU may show altered anatomy. The ureters drain into a neobladder.

on the position of the peristaltic wave. Contrast in the bladder shows the outline but is so dense that it will obscure small lesions within the bladder (Figure 1.1).

Before good quality ultrasound, CT, and MRI were available, almost total reliance had to be placed on the IVU. Various methods were used to improve its diagnostic quality. Bowel preparation in the form of laxatives was given to minimize the problem of overlying bowel contents. Patients were dehydrated to improve contrast excretion. Relatively high doses of contrast were used, particularly in patients with poor renal function, despite the nephrotoxicity of the contrast. The older, less well tolerated ionic contrast agent was excreted better than newer non-ionic contrast agents. Multiple films were often taken including oblique views, tomograms, delayed films, and fluoroscopic screening. Some older clinicians bemoan the fact that the quality of the IVU has deteriorated in recent years. It is well to remember that the high quality of the old IVU came at a price. At best there was greater patient discomfort, at worst actual morbidity and mortality. It

is right that centers where the IVU is still used accept the limitations of a simpler and safer technique knowing that they can gain whatever information is not obtained by other secondary imaging methods.

CLINICAL APPLICATIONS

Perhaps the most common use of the IVU now is in suspected ureteric colic. In many centers, however, the IVU is being replaced in this indication by low dose uncontrasted CT. Many studies show that CT is virtually as sensitive and specific as an IVU. Some show it to be significantly more sensitive. More importantly, CT, even low dose CT, detects significantly more pathology that mimics ureteric calculus colic. CT is safer as no contrast is given. The only disadvantages are a higher radiation dose (3.5 mSv for CT versus 1.5 mSv for IVU), and that no physiologic information is obtained.^{3,4}

It is also arguable that the IVU may still have a place in the investigation of macroscopic hematuria. Renal cell cancers and large bladder tumors are excluded by ultrasound, small bladder lesions are excluded by cystoscopy. The problem lies in the detection of upper tract transitional cell cancers. The percentage of cases of macroscopic hematuria that are due to upper tract transitional cell cancers is, however, small, and by no means all of those tumors present will be detected by an IVU. Because of this some argue that ultrasound and cystoscopy are sufficient, some would still add an IVU, and others use a CT with delayed secretory phase imaging.⁵

The IVU may still be used to outline the anatomy of the urinary tract. This is often necessary if the patient is thought to have anomalies or has had previous surgery the details of which are not known (Figure 1.1). The same information may, however, be obtained by CT and with modern reconstructive methods CT often gives superior information.

COMPUTED TOMOGRAPHY

Ultrasound and CT are now the mainstay of urologic imaging. Multislice CT with a 64-slice system can now achieve isotropic imaging. That is to say that the voxels that make up the image are the same thickness in all three dimensions. This means that a reconstructed image in any plane has the same resolution as the axial plane used for primary acquisition (Figure 1.2). This makes CT a very powerful imaging tool.

The spatial resolution of a modern multislice system is impressive with a voxel size of down to 0.6 mm. This

resolution, however, comes at the cost of relatively high radiation. A typical high resolution scan of the renal system carries a radiation dose of about 8 mSv for a two phase scan, about 16 times that of a plain abdominal film. The scan may be performed in several phases, such as, pre-contrast, arterial phase, venous phase, and excretory phase. If several or all of these are performed the dose is multiplied. Such extended studies are sometimes necessary and in these cases the radiation is accepted. In most cases, however, the information required may be obtained in one or two phases. In some circumstances high resolution is not necessary. For instance, renal calculi. Even those not visible on a plain film, are significantly more radiodense than soft tissue. If a CT is being performed for the detection or follow-up of calculi, a far lower dose technique may be used by lowering the mA and acquiring thicker slices. This method reduces the dose by a factor of two to about 2 mSv for a single phase.⁶⁻¹⁰ The signal to noise ratio is reduced and the resulting image is not pleasing to look at but is diagnostic (Figure 1.3). Calculus disease is an obvious example of when a reduced dose technique can be used but there are others where the technique can be used. This is particularly desirable when follow-up scans are needed.

Uncontrasted computed tomography

CT without intravenous contrast demonstrates the kidneys but with little or no tissue contrast between normal parenchyma and pathologic tissue such as tumor (Figure 1.4). The ureters are well shown though they are difficult to follow on a set of hard copy films. They are far easier to follow on a workstation by scrolling through the images. Bladder anatomy is shown though contrast resolution between tumor and bladder wall is poor. The main use of uncontrasted CT is to detect calculi (a low dose technique is usual). Uncontrasted CT is also sometimes used if contrast is contraindicated.

Contrast enhanced computed tomography

Contrast enhanced CT involves the intravenous injection of iodinated contrast (identical to that used in the IVU) that is excreted by the kidneys. Use of iodinated contrast in patients with impaired renal function or in patients taking metformin may worsen their condition. Use of iodinated contrast in such cases is not totally contraindicated but if used it must be clear that the



Figure 1.2 Computed tomography (CT) scan. This CT study demonstrates how CT may show anatomy. Between the images ((A) and (B) reconstructed coronal views, (C) and (D) sagittal views) the dilated ureters can be seen passing into an ileal conduit. Note also that the right ureteric wall is contrasted indicating ureteritis.

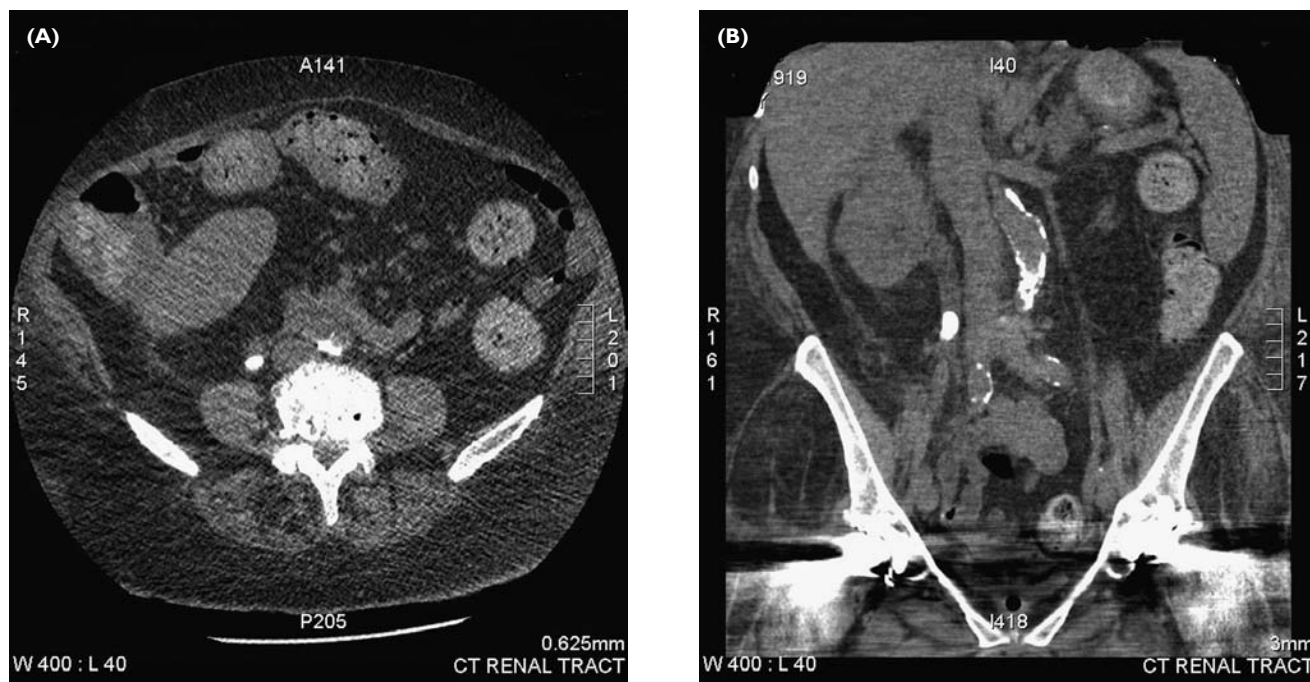


Figure 1.3 Low dose uncontrasted CT for the demonstration of calculi. (A) Axial view. (B) Coronal view. Although the images are very noisy (low signal to noise ratio) the calculus in the mid-ureter is clearly seen.

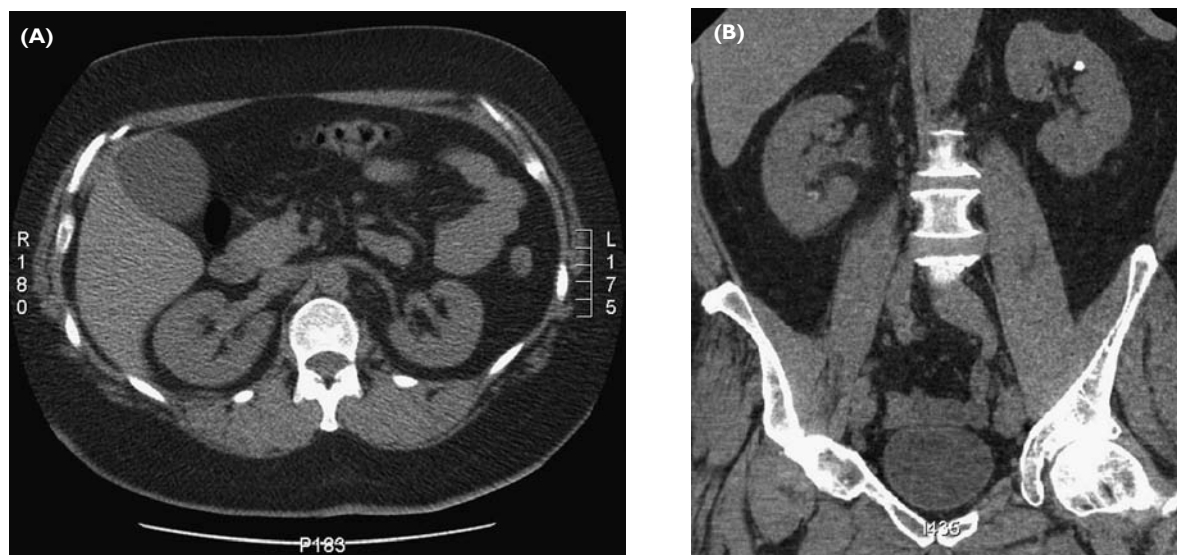


Figure 1.4 Uncontrasted CT scan. (A) Axial plane. (B) Reconstructed coronal plane. Although the kidneys and bladder are clearly seen, there is little parenchymal detail. For instance, there is no differentiation between cortex and medulla (though the left renal calculus is seen).

potential benefits of the study outweigh the possible morbidity.¹¹ There are also other relative contraindications to contrast including a previous contrast reaction, allergies, or asthma.

Image acquisition may be performed at any phase of the passage of contrast through the system. The phases used are principally the arterial, nephrographic, venous, and excretory phases. Although imaging in multiple

phases may be performed in a single examination, the radiation dose is high and it is more common to confine the examination to one or two phases depending on the information required. By careful timing, varying or splitting the contrast dose, two phases, usually the nephrographic and excretory phase may be combined. The timing of the sequences is made more accurate by 'smart' scanning where the CT scanner constantly

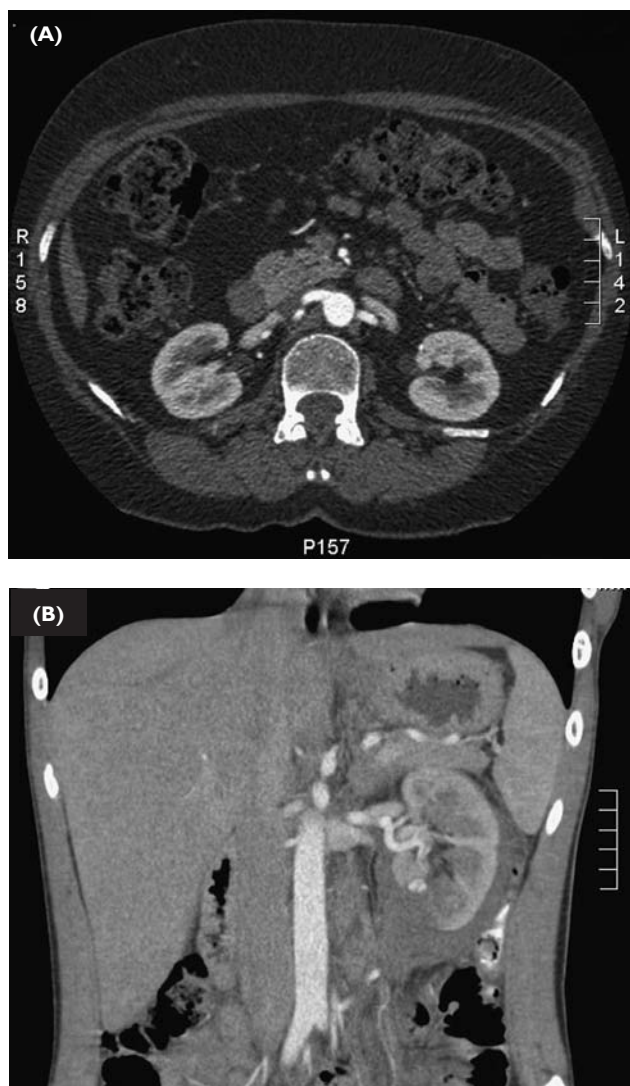


Figure 1.5 Arterial phase CT scan. (A) Axial view showing the right renal artery leaving the aorta. Because the vessels are not straight multiple images or ideally a workstation is needed to follow the vessels. (B) Images can be reconstructed in other planes or (C) a three-dimensional reconstruction can be produced which can be rotated on a workstation.

scans at low dose and detects when the bolus of contrast arrives at an appropriate artery. The start of the scan may therefore be set at an appropriate time interval after this event.^{12,13}

Arterial phase

The arterial phase demonstrates the arterial tree from the aorta to the interlobar arteries. With high resolution scanning the resolution of the larger vessels approaches that of a catheter angiogram (Figure 1.5), though the catheter angiogram still has better resolution in small vessels (see Figure 1.29). The CT image may be reconstructed in any plane or a pseudo three-dimensional image may be constructed^{14,15} (Figure 1.6). Some digital catheter angiography systems also have this capability. The technique is, however, rarely used as now most or all diagnostic angiograms are performed by CT

angiography, catheter angiograms being reserved for interventional procedures.

Arterial phase CT angiography is most often used for suspected renal artery stenosis. It has other applications, however, including assessment of potential live kidney donors and for mapping the vessels when planning for procedures such as partial nephrectomy.¹⁶

Parenchymal or venous phase

The parenchymal and venous phases overlap and may be regarded together. It is this phase that gives the best contrast resolution between normal renal parenchymal tissue or bladder wall and pathologic tissue such as tumor (Figure 1.7). As there is contrast in the veins, the venous system can also be mapped. The most common reason for studying the veins is to assess whether a renal tumor has invaded the vena cava in order to

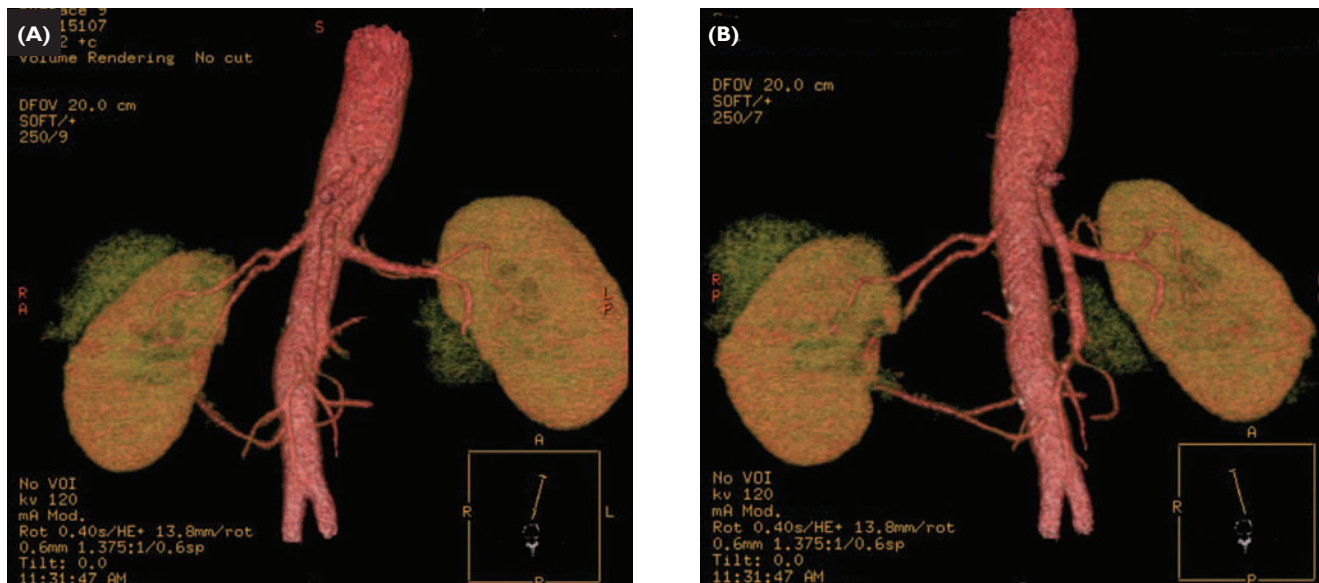


Figure 1.6 Three-dimensional reconstruction. (A) and (B) Still views of a reconstructed image from a potential live kidney donor, clearly showing the vascular anatomy. On a workstation these images can be rotated and viewed from different angles. The color rendering, although attractive, adds no diagnostic information.

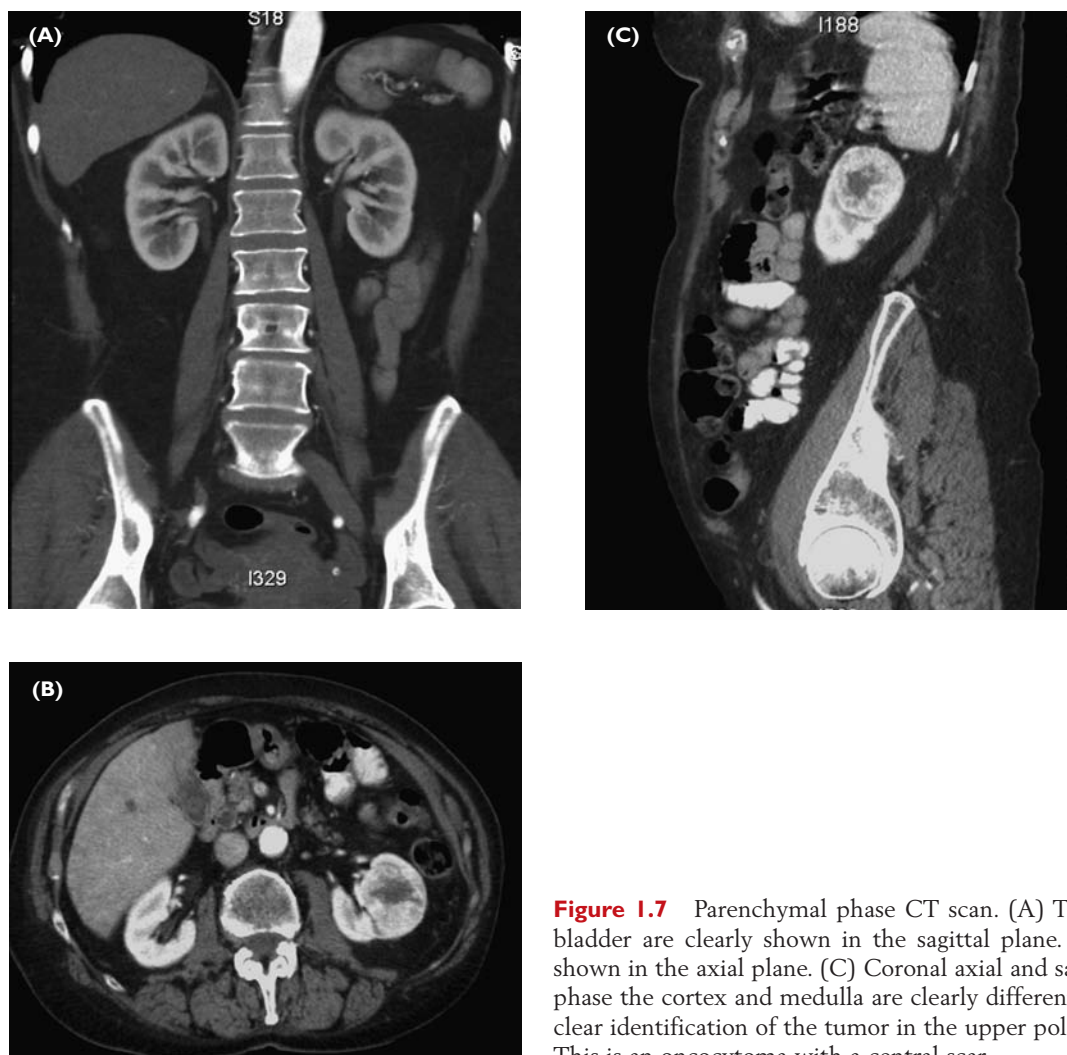


Figure 1.7 Parenchymal phase CT scan. (A) The urethra and the bladder are clearly shown in the sagittal plane. (B) The urethra is shown in the axial plane. (C) Coronal axial and sagittal views. In this phase the cortex and medulla are clearly differentiated. There is also clear identification of the tumor in the upper pole of the left kidney. This is an oncocytoma with a central scar.



Figure 1.8 Venous phase CT scan. Contrast is seen in the right renal vein and part of the inferior vena cava (IVC). Because of this the tumor thrombus in the left renal vein is outlined.

plan surgery; however, MRI may be preferable¹⁷ (Figure 1.8). The calyceal system and ureters are not opacified at this stage and appear similar to their image on an uncontrasted scan. It is possible to reduce the dose of contrast in this phase to a level where the parenchyma is contrasted but not to a degree that obscures renal calculi.

Late or excretory phase

In the late or excretory phase contrast fills the pelvicalyceal system, ureters and bladder. Similar information is given to that provided by an IVU.¹⁸ This phase is useful for mapping anatomy. The image may be reconstructed in any plane. The most common planes used are coronal and sagittal (Figure 1.9), though other planes, including curved planes may be constructed. In practice, however, reconstructed images give no more information than is obtained by scrolling through standard image planes on a workstation. This phase may also identify uroepithelial tumors in the calyceal system or ureters, though sensitivity is relatively low. Small bladder tumors may be obscured by contrast in this phase. Bladder tumors are best assessed in the arterial phase when the wall is contrasted and the lumen is not opacified (Figure 1.10).

MAGNETIC RESONANCE IMAGING

MRI has relatively poor spatial resolution compared with CT, is more prone to artifacts, and more expensive

than CT. It is therefore used less often in the genitourinary tract. It does, however, involve no radiation and so may be used in pregnancy or when multiple repeat scans are needed.^{19,20} It does not require iodinated contrast so may be used in patients with renal failure, contrast allergies, or asthma.

The physical principles of MRI⁵ are extremely interesting but are not discussed further in this chapter. Nor is an understanding of the physical principles absolutely essential to interpretation of the images. Suffice it to say that MRI produces its images by causing magnetic excitation of the protons and then collecting the signals that they emit when they relax. As protons are most abundant in hydrogen, MRI images are based on the distribution and density of hydrogen atoms. This distribution and density varies in different tissues and also in disease states.^{21,22}

MRI images may be produced in a large number of different ways or sequences. There are four basic sequences that are commonly used and the others are variations on these. These sequences are T2 weighted, T1 weighted, fat suppressed, and contrast enhanced images.^{23–25} There is insufficient space here to explain in detail what these images entail or how they are produced. The reader is referred to one of the many excellent MRI texts that are available.^{21,22} Only brief discussions follow.

T2 weighted images

T2 weighted images strongly reflect hydrogen density. As hydrogen density is highest in water, aqueous fluids produce a strong signal and appear white on the image. Fat also appears white or pale gray. Many pathologic tissues are edematous. These tissues, as they contain more water, have a higher signal than healthy tissue (Figure 1.11).

T1 weighted images

T1 weighted images are the images that traditionally were used to demonstrate anatomy. As higher magnetic field strengths have become available, however, T2 weighted images that show pathology well also demonstrate the anatomy well. In many cases therefore only T2 weighted images are needed. T1 weighted images are reserved for those cases where a comparison of the T1 and T2 tissue signal helps in tissue diagnosis (Figure 1.12).

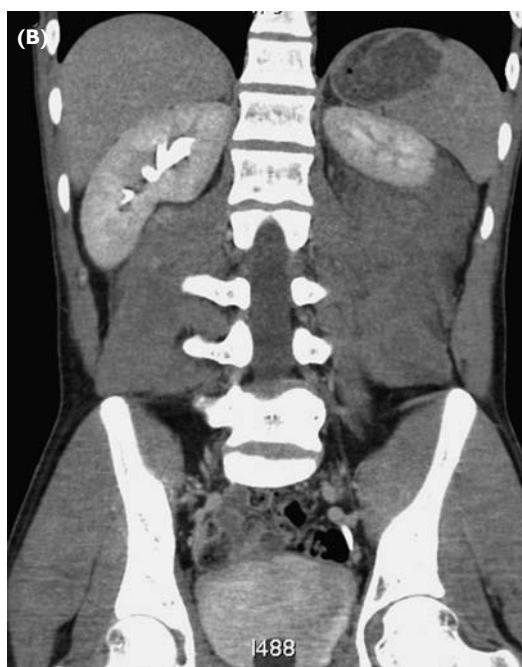


Figure 1.9 Excretory phase (late phase) CT scan. (A–D) Show there is contrast in the ureter. Only small portions are shown in each single image but on a workstation the ureters can be easily followed.

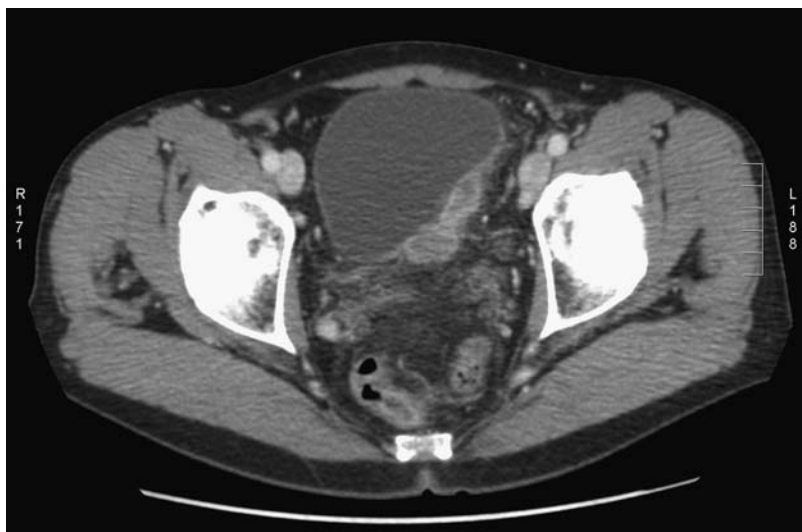


Figure 1.10 Arterial phase CT scan of the bladder. The wall of the bladder is enhanced outlining the tumor in the left wall.

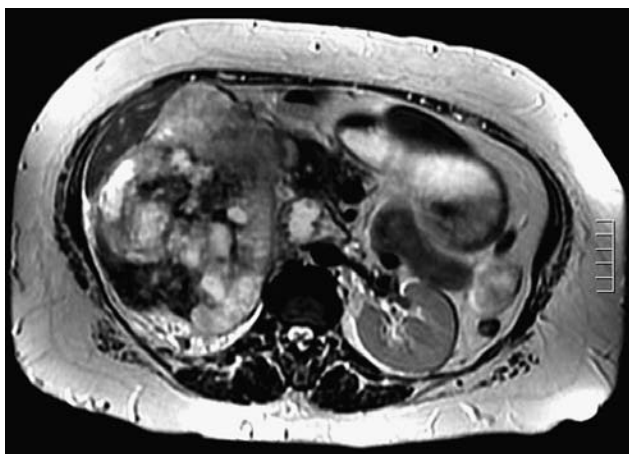


Figure 1.11 T2 weighted magnetic resonance image (MRI) scan. This clearly shows the anatomy of the left kidney. The large tumor in the right kidney is also clearly demonstrated.

Fat suppressed images

Fat suppressed images as the name implies suppress signals from fat on a T2 weighted scan. This may be achieved in a number of ways but whatever method is used the effect is the same. Fat loses its signal and therefore appears dark on the image while other tissues with high hydrogen content remain high signal. In some instances the reason for fat suppression images is to differentiate pathologic tissue from fat, while in other cases it is to show that fat is present in a lesion, for example, for the characterization of an angiomyolipoma. The image is often low grade which needs to be viewed alongside the corresponding T2 weighted image for interpretation (Figure 1.12).

Contrast enhanced images

The contrast agents used in the vast majority of contrast enhanced MRI studies are gadolinium based agents. These are nephrotoxic, but not to a sufficient degree to cause concern. Until recently they were regarded as otherwise safe. In the last year however a condition has been described that has been labeled nephrogenic sclerosing fibrosis. This is a multi-system disorder affecting patients in renal failure. It is characterized by fibrotic skin lesions, sometimes leading to contractures. In some cases fibrosis of multiple organs has been described and deaths have occurred from the condition. There is no effective treatment. It has further been found that many of the patients with this condition have had gadolinium based contrast agents prior to the onset of the disease. Gadolinium has been detected in the fibrous lesions. It is likely therefore that gadolinium is implicated in the disease process. Because of this it is currently recommended that gadolinium contrast agents should not be given to patients with severely impaired renal function and perhaps also not to those with moderately impaired renal function. This remains prudent advice until more is known about the condition.

Contrast enhanced images utilize the fact that MR contrast agents, although not visible themselves on MRI, change the state of the adjacent protons so that their T1 and T2 states and therefore the signals that they emit are altered. This has an effect on the image similar to contrasted CT, though the physical principles are quite different. The main contrast used is gadolinium. This is initially contained within the intravascular space. MR angiography images may therefore be obtained. While these images have less spatial resolution and more artifacts than a contrasted CT image, they can

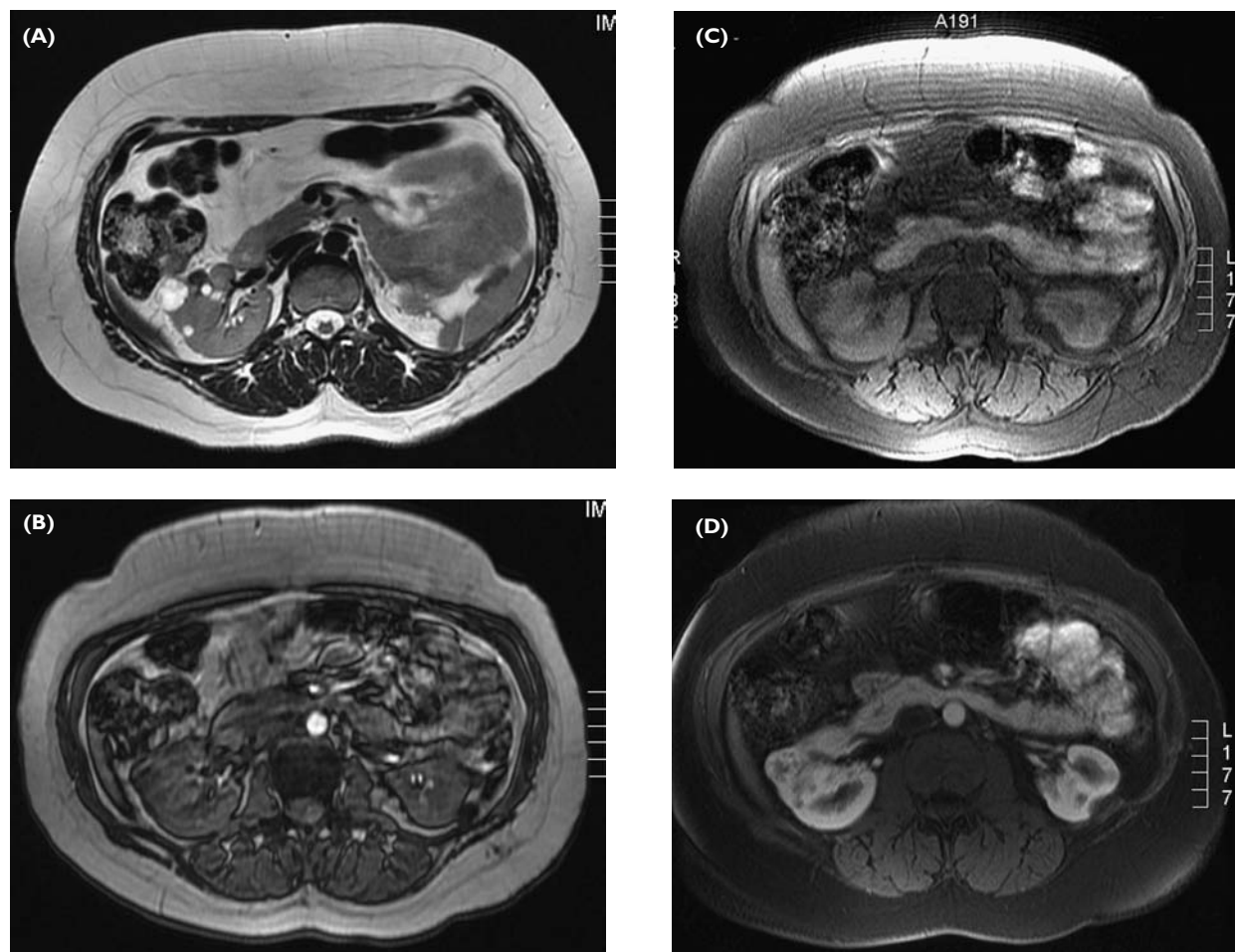


Figure 1.12 Series of MRI sequences. This series demonstrates how different sequences can categorize lesions, in this case in a patient with von Hippel-Lindau disease. (A) T2 weighted image, (B) T1 weighted image, (C) fat saturation image, and (D) fat saturation image with contrast. This sequence shows that the larger lesion in the right kidney has a high T2 signal, medium T1 signal, contains no fat as shown on the fat saturation image, and enhances with contrast. This characterizes it as a renal cell cancer.

nevertheless be diagnostically useful²⁶ (Figure 1.13). Angiographic MRI images may also be obtained without the use of intravenous contrast. The sequences used may utilize the fact that moving blood has an altered signal, or in another method the fact that the blood is moving within the vessels. If the blood contained within an MR slice is excited but has moved on by the time the signal is detected, then the excited blood is replaced by non-excited blood which is seen as a signal void. There are other more complex methods. These methods, however, while novel and not requiring contrast, lack the resolution of a gadolinium enhanced angiogram and are now little used.

Contrast perfusion

Gadolinium enhanced images may also be used to produce studies which reflect tissue perfusion (Figure 1.14).

As with any contrast agent the change in concentration of gadolinium in a tissue may be plotted against time. This may be used to distinguish normal from abnormal tissue. Such studies, while possible, are time consuming and have not proved so far to be sufficiently sensitive or specific to be useful in routine clinical practice. Gadolinium is also excreted by the kidneys; however, this feature is seldom utilized in MR imaging.^{27,28}

Tissue specific contrast agents

MRI contrast agents have been and are being developed that are taken up by specific tissues, enabling study of the tissues.²⁹ An example is small particle iron oxide (SPIO). Iron oxide particles are taken up by the reticuloendothelial cells. Where present, they cause low signal, as they are paramagnetic. This can be used

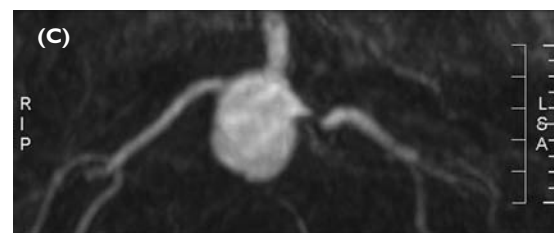


Figure 1.13 Gadolinium enhanced MR angiogram. The vascular pattern is clearly demonstrated, as is the left renal artery stenosis. (A–C) Different angulations can be used to effect.

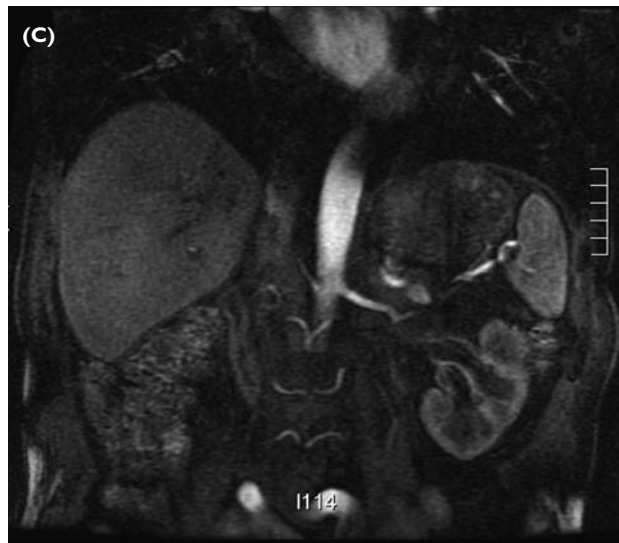
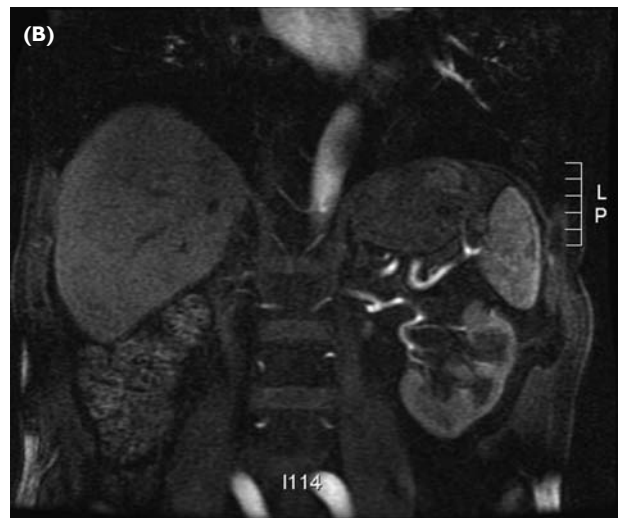


Figure 1.14 Gadolinium enhanced MRI studies. (A–C) The vascular pattern is well demonstrated, and the enhancement pattern of the kidney can also be assessed.

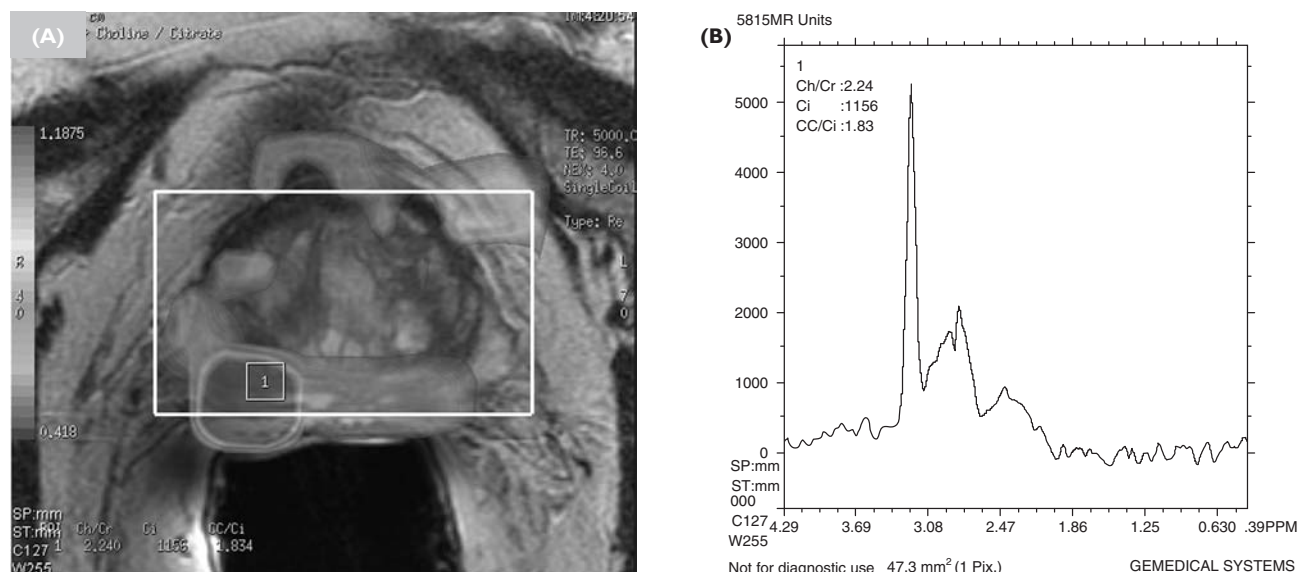


Figure 1.15 MR spectroscopy. This is a study of a prostate gland for suspected cancer. (A) A small volume of the peripheral zone has been selected. This is outlined by the smaller box. (B) Spectral analysis, the two larger peaks representing citrate and choline.

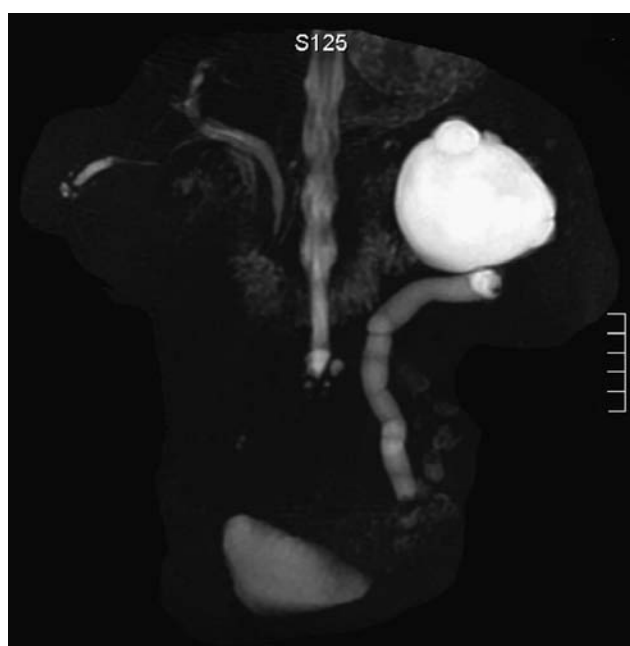


Figure 1.16 MR urogram. This heavily T2 weighted study shows fluid filled structures. The hydronephrotic left kidney and hydroureter are well demonstrated as is the normal right upper ureter and the bladder. The central structure is cerebrospinal fluid in the spinal canal.

for tissue characterization, for instance, to distinguish normal, infected, or reactive lymph nodes that contain reticuloendothelial tissue from malignant nodes where the reticuloendothelial tissue has been replaced by tumor.

MR spectroscopy

MR was originally developed as a tool for the spectroscopic analysis of chemical compounds. MRI depends almost entirely on hydrogen density as this produces the strongest signal. Nevertheless, spectroscopic analysis of the other elements within a small volume or multiple volumes of tissue within an MRI slice is possible. This has found a number of uses, for instance, in the measurement of citrate and choline peaks in the prostate gland.^{30,31} The normal ratio is reversed in prostate cancer, making tissue differentiation theoretically possible (Figure 1.15). Initial enthusiasm for this very exciting technique has been tempered by disappointing results in subsequent studies. The current trend towards higher power clinical MRI machines, principally 3 T as opposed to the common 1.5 T magnet strength now in use, may improve the technique.

MR urogram

T2 weighted images produce high signal from aqueous fluid including urine. A heavily T2 weighted image therefore makes the calyceal system, ureters, and bladder very bright compared to the surrounding tissue. Such an image often viewed in the coronal plane is termed an MR urogram (MRU)³² (Figure 1.16).

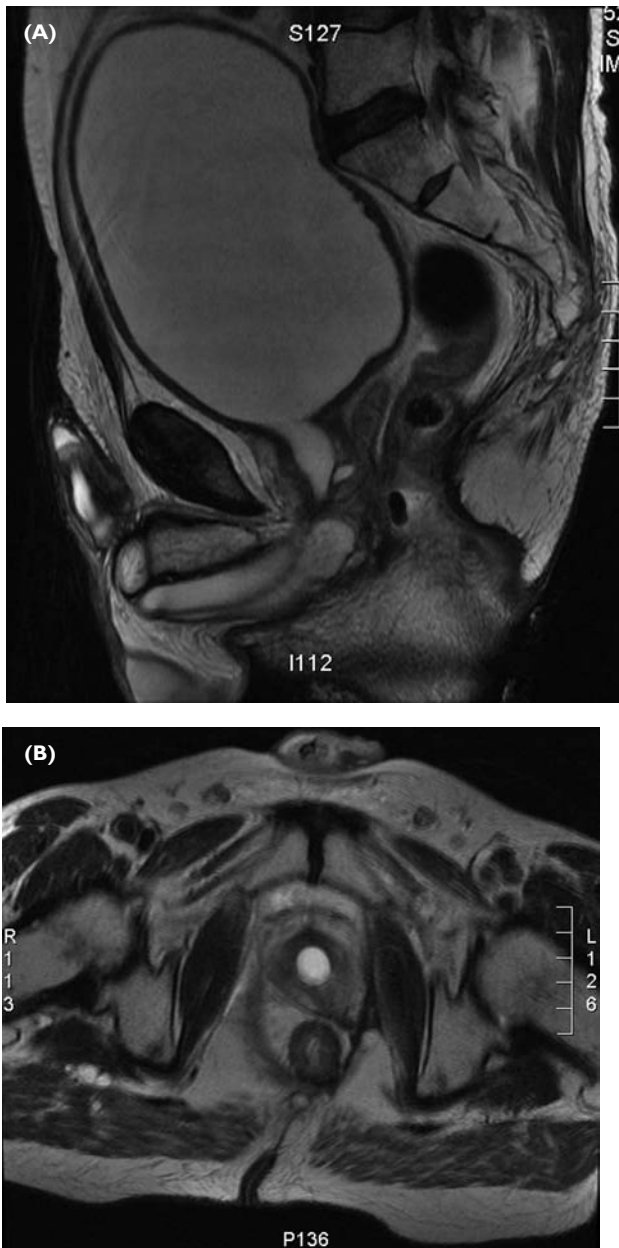


Figure 1.17 MR urethrogram. This is a heavily T2 weighted study performed with gel in the urethra. (A) The urethra and the bladder are clearly shown in sagittal plane. (B) The urethra is shown in the axial plane.

MR urethrography

A technique has recently been described in which the urethra is filled with aqueous gel and T2 weighted MRI is then performed.³³ This outlines the urethra in a similar way to a contrast urethrogram. It has the added advantage that the tissues around the urethra are also demonstrated (Figure 1.17). MRI is also probably the best method of imaging the female urethra (see also the Imaging of the urethra section below).

ULTRASOUND

As with CT and MRI a detailed account of the physical principles of ultrasound is outside the scope of this chapter. Many good accounts are available.³⁴ It is relevant, however, to discuss briefly recent developments in ultrasound.³⁵

The first ultrasound machines transmitted beams of high frequency sound that were reflected at tissue interfaces. The reflected beams were received by the same transducer and analysed. Depending on the time taken for the echo to return a dot could be placed on the image screen that represented an interface. Other interfaces at different depths were represented by other dots along the line, their brightness representing the strength of the reflection from the interface. When many of these lines were displayed side by side then a two-dimensional image was created.

Modern machines use exactly the same basic technique; however, more complex principles are superimposed. Over the years improvement in the basic design of transducers and receivers, and the superimposition of other methods of image processing have achieved a gradual but dramatic increase in image quality. This improvement has led to the survival of ultrasound alongside the more recent developments of CT and MRI.

Real-time imaging

Ultrasound systems operate in real time. This means that the operator sees a moving image reflecting the continuously changing planes as the transducer is moved. With experience, hand-eye co-ordination becomes such that the transducer movement is intuitive. There are many controls that alter the image. An experienced operator will continuously adjust these to optimize the information obtained. It is important to realize that although a good operator will obtain a set of still images that display the examination and pathology found as clearly as possible, these cannot fully reflect the real-time information obtained by the operator. This makes ultrasound the most operator dependent modality in use. Modern PACS (picture archiving and communications system) systems can support video clips but in some cases trust must be placed on the interpretation of the operator.

IMPROVEMENTS IN BASIC DESIGN

A major part of the increase in image quality has been the development of more efficient transducers. These

produce a more evenly focused ultrasound beam nearer to the theoretical ideal narrow parallel beam than produced by older machines. Modern transducers also function at a wide range of frequencies. This is essential to some of the other improvements discussed later. The image processing is complex and a thorough understanding is not essential to the user of ultrasound equipment. Many of the functions are programmed into the machine and the operator has little or no control over them. Some, however, are under operator control and these need to be understood in order to optimize the examination.

Tissue harmonic imaging

Tissue harmonic imaging is a fairly recent innovation. It was found that when an ultrasound beam strikes tissue, not only is it reflected at the interfaces, but also the pressure of the beam causes the tissues to vibrate. This vibration occurs not only at the frequency being transmitted, but also in a wide band of frequencies both above and below. With a broadband transducer, all these frequencies may be received. Although these non-fundamental frequencies are weaker than the fundamental frequency, if they are selectively used to produce the image, then the image is subtly changed from the fundamental image. In modern high range machines the image may be switched from fundamental to tissue harmonic and in some cases a fused image of both may be displayed.

The theoretical advantage of tissue harmonic imaging is that when an ultrasound beam is passed through tissue it is not only reflected but also diffracted. This diffraction degrades the image. With fundamental imaging the beam that produces the image passes through the tissues twice, with tissue harmonics only the beam from the excited tissue produces the image so that there is only one passage. Tissue harmonic imaging therefore, theoretically produces a less degraded image particularly in deeper structures; however, it is clear from clinical use that this is an oversimplification. Different patients and different tissues react differently so that in some cases the tissue harmonic image may be clearer, while in others the fundamental image is clearer. Interestingly, the echo pattern of some pathologic tissues differs in both methods. This may have potential in tissue characterization.

Compound imaging

Spatial compounding is a technique that started with the original non-real-time compound B scanners. Experienced operators would pass the probe across

the patient's skin not in a single even sweep but using a number of oscillations along the path. Modern scanners may achieve the same thing by electronic steering of the beam. The result is that the image is viewed from several different angles. Combining these into a single image increases spatial resolution.

Frequency compounding is achieved by combining the image obtained from a number of different frequencies. In general, higher frequencies give better spatial resolution but poor depth quality, and lower frequencies the reverse. Machines constantly change frequencies with depth to optimize these qualities. There are, however, other differences in the image with different frequencies. If the images produced by different frequencies are fused this has some advantages.

While both types of compounding may improve image quality they also cause artifacts. It would therefore be inappropriate to have them switched on at all times. In practice, the operator will switch between compounded and non-compounded images to gain maximum information.

Clinical applications of gray scale imaging

Diagnostic ultrasound is safe, cheap, easily available, and gives a great deal of information about the urogenital tract. It is the imaging modality that is used almost exclusively in the scrotum (MRI may rarely be used). For many urogenital pathologies it is the initial and often the only modality used; however, it does have significant limitations. It is far more operator dependent than other imaging modalities, though with experienced operators this should not be a major problem. The image quality is degraded in large patients though top of the range machines may largely overcome this. The main limitation in the urinary system is that the non-dilated pelvicalyceal system and ureters are only poorly seen.³⁶

Ultrasound demonstrates the kidneys as medium echodensity structures with the renal pyramids shown with varying clarity as rounded triangular structures of lower echodensity than the cortex. The pelvicalyceal system together with the paracalyceal fat is seen as a hyperechoic white complex structure lying centrally. The pelvicalyceal system may be seen as an anechoic structure as may the renal pelvis. The non-distended system is seen with varying clarity, certainly not sufficiently well to exclude uroepithelial tumors (though they are often detected) or even to detect most duplex systems with certainty. The distended system is more clearly seen (Figure 1.18).

The ureters may be seen at their upper ends by scanning through the lower pole of the kidneys. The lower ureters may be seen by scanning through a

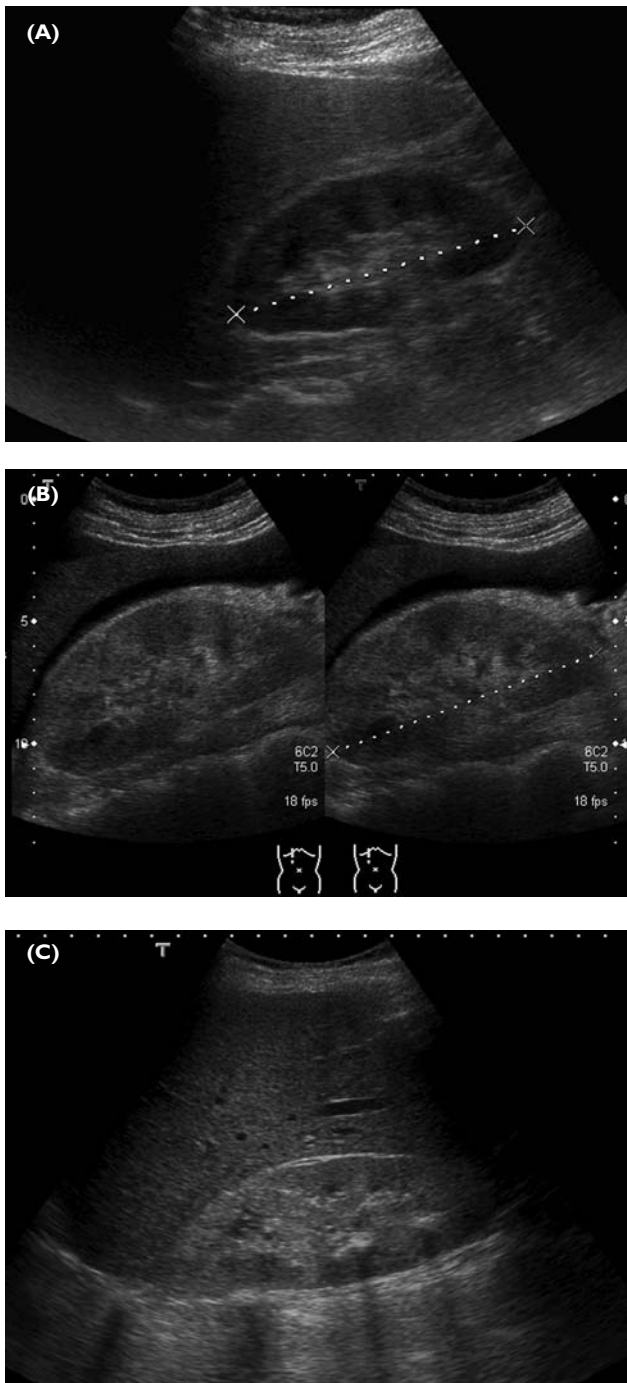


Figure 1.18 Renal ultrasound. (A) Normal kidney demonstrating the clear differentiation between cortex, medulla, and central complex. By contrast (B) shows a case of acute renal failure where the cortical medullary differentiation is lost and there is perinephric fluid. (C) There is a loss of corticomedullary differentiation in this case of chronic renal failure.

reasonably full but not over full bladder. The mid-part of the ureters may often be seen as they cross the iliac vessels. The rest of the ureters unless distended are poorly seen or not seen at all (Figure 1.19). There are

some recent studies that suggest that real-time three-dimensional ultrasound, often referred to as '4D', may more successfully map the distended ureters and may display the cause of obstruction. The technique is, however, still significantly inferior to CT, MRI, or IVU. Technical advances in volume acquisition 4D may change this situation in the future.

The retroperitoneum is in general poorly visualized by ultrasound, although retroperitoneal structures may be well seen in some, particularly in slim patients. Some areas are often obscured by bowel gas. Large tumors or pathology may be seen but for instance the retroperitoneal lymph nodes are certainly not sufficiently well seen to stage urologic tumors.

The bladder is reasonably well visualized by ultrasound. The shape and size is well demonstrated and bladder volume may be estimated sufficiently accurately to study bladder emptying. Structural anomalies such as diverticula and ureterocele are well demonstrated. The augmented or reconstructed bladder is adequately assessed by ultrasound (Figure 1.20).

Thickness of the bladder wall can be assessed. The serosal, muscularis, and mucosal layers can be distinguished with good quality equipment though not sufficiently reliably to stage bladder tumors for which MRI is the best modality, and CT second best.

Most bladder tumors can now be detected by ultrasound (Figure 1.21) though cystoscopy remains the gold standard and has the advantage of the facility to biopsy any lesions seen.

Doppler imaging

Doppler imaging is a method of displaying moving structures or tissue (principally flowing blood) and measuring their velocity. It utilizes the Doppler principle that a body moving in relation to a sound source will alter the frequency of the reflected sound to a degree proportional to its velocity. In diagnostic ultrasound systems the frequency altered signals can be displayed by a color map (color Doppler) (Figure 1.22), or in the form of a graph plotting frequency shift, which is proportional to velocity against time (spectral Doppler) (Figure 1.23).

Power Doppler is a technique that processes the altered signal in a power domain rather than a frequency domain. It is more sensitive and less dependent on the angle of the vessel in relation to the ultrasound beam. It does not give directional information. Although power Doppler is theoretically more sensitive, frequency domain Doppler systems have improved to such an extent that there is now little difference. In some systems the two modalities can be combined.

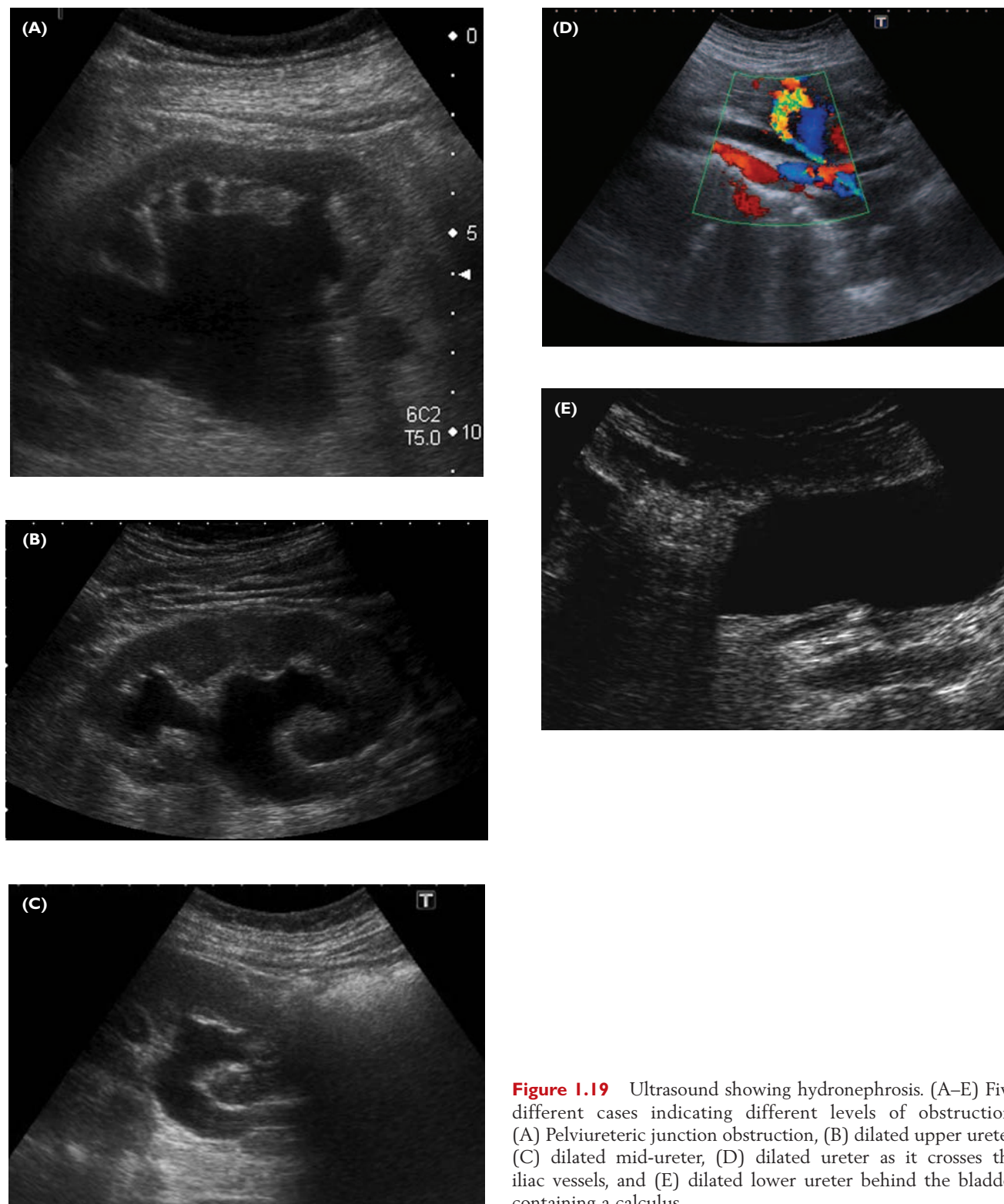


Figure 1.19 Ultrasound showing hydronephrosis. (A–E) Five different cases indicating different levels of obstruction. (A) Pelviureteric junction obstruction, (B) dilated upper ureter, (C) dilated mid-ureter, (D) dilated ureter as it crosses the iliac vessels, and (E) dilated lower ureter behind the bladder containing a calculus.

Some machines can produce a color flow map similar to a color Doppler image that does not use the Doppler principle but compares several consecutive frames and detects the change in pixels from moving structures. This produces a cleaner image with no color bleed outside the vessels.

In practice, none of these techniques has an overall advantage and where available each is used appropriately.

Ultrasound contrast agents in the form of stabilized microbubbles injected intravenously greatly enhance the Doppler signal. This is sometimes, though infrequently, necessary for straightforward Doppler studies but the

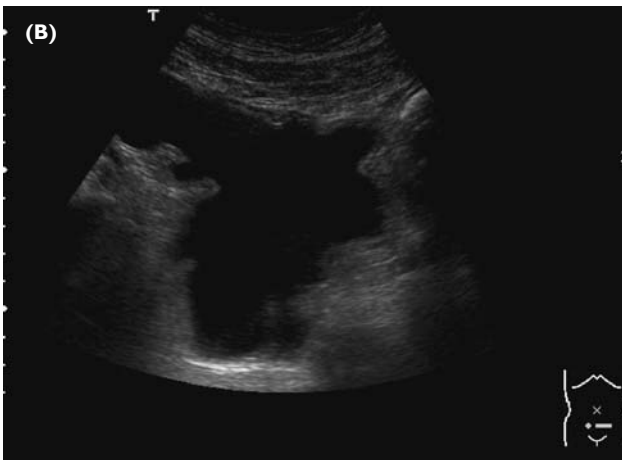
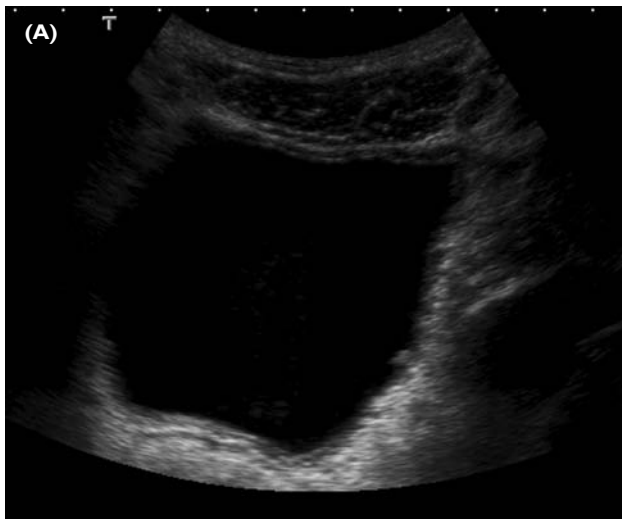


Figure 1.20 Ultrasound studies of the bladder. (A) The layers of the bladder wall are clearly seen on the anterior and posterior wall but not laterally. There is a very small papilloma on the left wall. (B) and (C) Axial and sagittal views of a cecocystoplasty showing how ultrasound can demonstrate a reconstructed bladder.

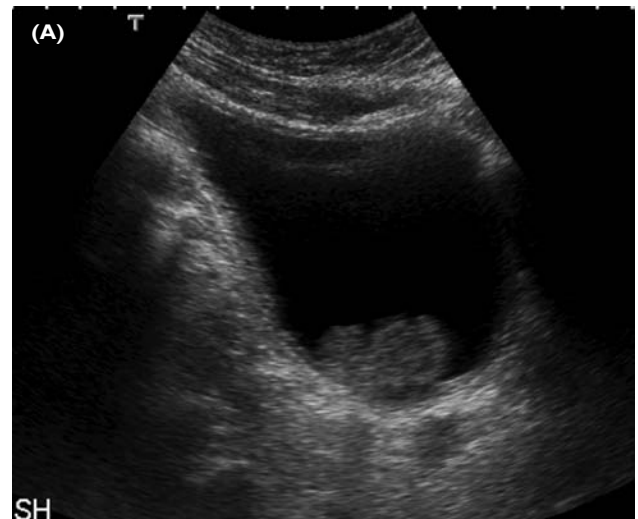


Figure 1.21 Ultrasound studies of bladder tumors. (A) The tumor on the posterior wall is clearly seen. (B) There is a tumor in a bladder diverticulum which extends through the neck into the bladder.

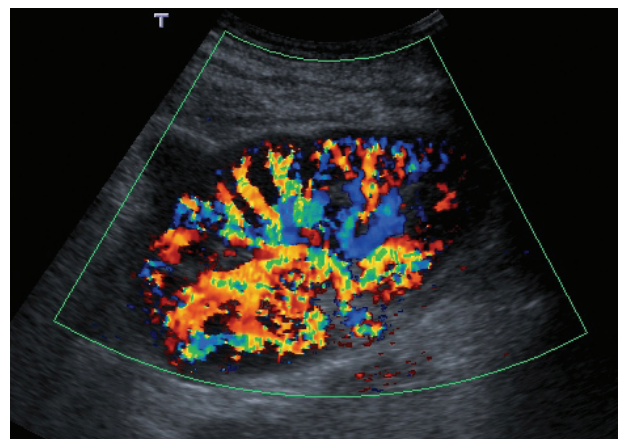


Figure 1.22 Color Doppler study. The intrarenal vessels are clearly demonstrated.

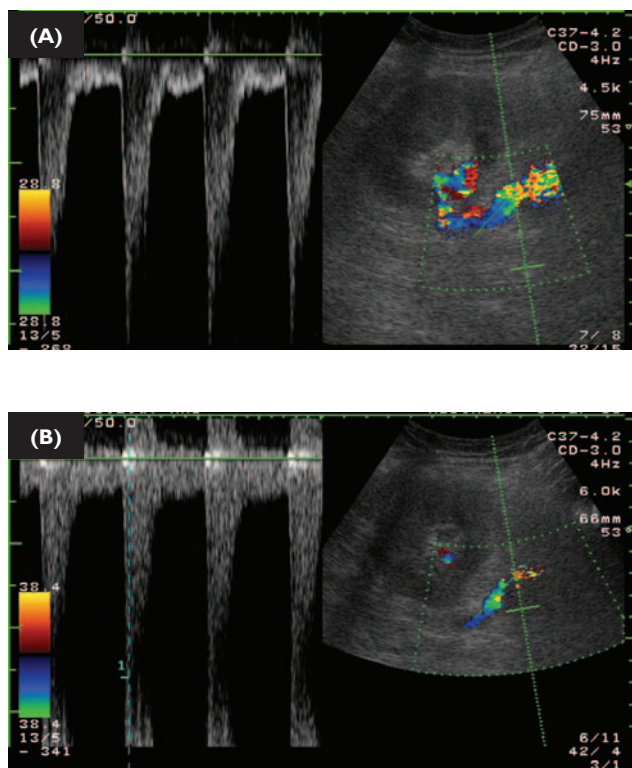


Figure 1.23 Color flow and spectral studies (duplex study). In this case (A) very high velocities are shown through a renal artery stenosis. (B) Just distal to the stenosis is high velocity and flow disturbance (turbulence).

technique has potentially exciting uses in microvessel imaging. These are discussed later in the chapter.

Clinical applications of Doppler ultrasound

The renal arteries and veins can be visualized ultrasonically using a color Doppler technique and their blood flow pattern analyzed by spectral Doppler. The technique can be used to assess renal perfusion and also to detect renal artery stenosis, though sensitivity is relatively low. Doppler studies do have a theoretical advantage over other vascular imaging techniques in that spectral wave forms may be obtained. These give physiologic information about blood flow patterns. This information may be related to pathology, for instance the high velocity at a stenosis, the turbulent flow just beyond, and the damped flow distally may confirm the diagnosis of a hemodynamically significant stenosis. Another example is increased vascular resistance resulting in reduced diastolic velocities seen in a range of renal parenchymal diseases, most notably acute tubular necrosis (ATN).

Contrast enhanced ultrasound

Another relatively new method of imaging the vasculature including very small vessels is contrast enhanced ultrasound (CEUS). In this technique stabilized gas containing microbubbles approximately the size of red blood cells are injected intravenously. These are contained within the vascular space. These bubbles are many times more reflective than red blood cells and therefore enhance the Doppler signal from flowing blood. The technique was originally intended to improve Doppler studies with a weak signal. Doppler systems have improved to such an extent, however, that this application, although still occasionally used, is now seldom needed. A newer application is a study of the microvasculature and perfusion of tumors and tissues. This requires specific software. Although the microbubbles are highly reflective, their concentration and velocity in the very small vessels being studied is low. The echoes returned from them in a conventional B mode or Doppler study are so weak that they are obscured by the gray scale tissue echoes. Contrast specific imaging is a generic term for a number of software driven techniques that achieve microvessel imaging. They all rely on the fact that when microbubbles are struck by a beam of ultrasound they vibrate. Furthermore, they vibrate in a non-linear fashion. By contrast, the frequencies returned from the gray scale image are linear. Therefore, if the fundamental frequencies are removed from the image (there are several ways of achieving this) then the frequencies left produce an image that is almost purely that of the vibrating bubbles, in other words a vascular or perfusion image.³⁷

Clinical applications of contrast enhanced ultrasound

This technique has achieved clinical use in a characterization of liver tumors where, as well as the vascular pattern, the dual blood supply via the hepatic artery and portal vein produces characteristic tumor perfusion patterns. Use in the urogenital system is at present experimental. The technique has been used in the detection of prostate cancer, in the characterization of renal tumors and in the study of perfusion patterns in renal parenchymal disease^{38,39} (Figure 1.24). Contrast agents may also be introduced into any body cavity and have been used as a form of cystography in the investigation of vesicoureteric reflux in order to avoid radiation.

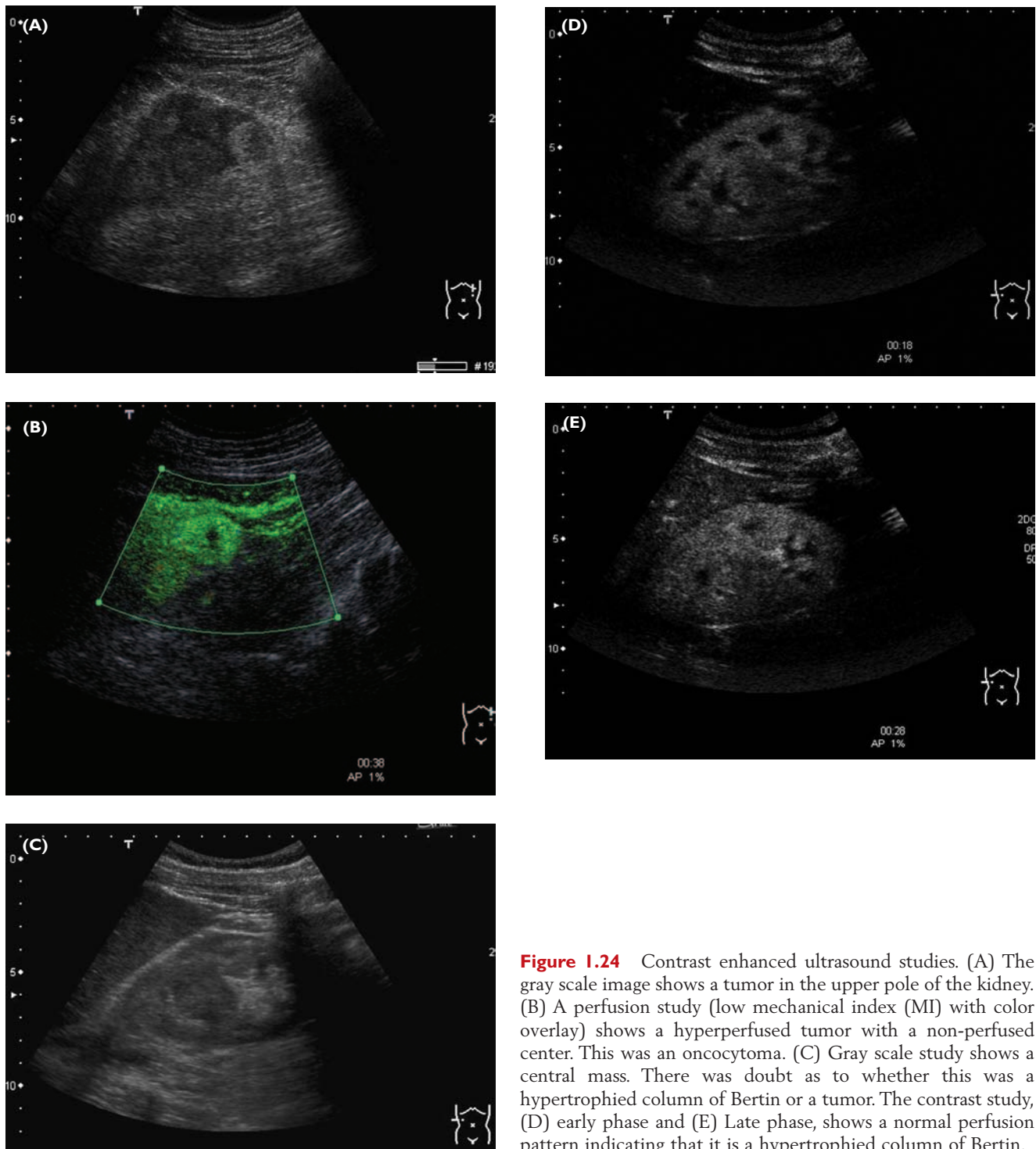


Figure 1.24 Contrast enhanced ultrasound studies. (A) The gray scale image shows a tumor in the upper pole of the kidney. (B) A perfusion study (low mechanical index (MI) with color overlay) shows a hyperperfused tumor with a non-perfused center. This was an oncocytoma. (C) Gray scale study shows a central mass. There was doubt as to whether this was a hypertrophied column of Bertin or a tumor. The contrast study, (D) early phase and (E) Late phase, shows a normal perfusion pattern indicating that it is a hypertrophied column of Bertin.

Real-time three-dimensional (4D) imaging

Three-dimensional imaging is now commonplace in CT. If sufficient slices close enough to each other are obtained then it is possible to reconstruct an image from this volume of data in any dimension. Attempts have been made

for a long time to achieve this with ultrasound. The main problem with ultrasound is to obtain slices that are accurately positioned in relation to each other. Another problem is the shadowing artifacts produced by gas and bones. Nevertheless, three-dimensional ultrasound imaging is now possible using a variety of techniques.⁴⁰

As ultrasound is practiced in real time with a moving image, it is desirable that the three-dimensional image should also be available in real time. This has been termed 4D. At the time of writing three-dimensional ultrasound images are often not ideal and contain artifacts; however, rapid improvements are being made and the technique shows great promise. It has achieved clinical use in the obstetric field. In non-obstetric imaging applications are emerging that are as yet not in widespread clinical use. There have been studies on its use in visualising the ureters and bladder.¹⁰

Imaging of the urethra

Contrast fluoroscopy (X-ray) urethrography remains at present the most commonly used modality for urethral imaging.

The male urethra may also be studied ultrasonically by a technique termed sono-urethrography. The urethra is filled with fluid, either by instilling fluid via the meatus, as with a contrast urethrogram, or by mic-turating with the glans penis pinched between finger and thumb. The urethra is then scanned with a high frequency high resolution transducer. Very good images may be obtained. The technique has the advantage over conventional contrast urethrography that the soft tissues around the urethra are also seen. Fistulae and fissures are, however, less well shown ultrasonically than by contrast urethrography. Sonourethrography is easy to perform and has significant advantages.¹¹ Despite this it is at present only performed in a few centers. It is possible that the recently described technique of MR urethrography will supersede it⁴¹ (Figure 1.17).

The female urethra is poorly seen with ultrasound though it may be visualized, visualization being made easier if there is a canula in situ. Using this technique the angle between the urethra and the bladder base may be measured to study female incontinence; however, MRI is arguably easier to interpret.⁴²

Transrectal ultrasound

The prostate and seminal vesicles may be seen trans-abdominally. The size of the prostate and the presence or absence of the seminal vesicles may be assessed. For more detailed study the transrectal route is necessary using an appropriate intracavitary transducer.

The most common use of transrectal ultrasound of the prostate is to aid the accurate placement of biopsies for

the detection of prostate cancer. This is not relevant to this book. It does have other roles, one being the investigation of infertility, principally in patients with obstructive azoospermia. In many centers the treatment of such patients is sperm retrieval from the testis. If this is the case then determination of the cause of the obstruction is unimportant. Some centers will seek to treat suitable cases surgically in which case ultrasound has a place.

The seminal vesicles are well visualized and the vasa deferentia are seen as they enter the prostate (Figure 1.25). Visualization of the full length of the vasa deferentia requires the use of MRI (Figure 1.26). The ejaculatory ducts may just be visualized as fine linear structures as they pass through the prostate.⁴³ Obstructed ducts, being dilated, are more easily seen as are calculi in the ducts. Müllerian duct cysts are also easily visualized. They are common and most are asymptomatic but some may cause obstruction.⁴⁴

Seminal vesiculography is conventionally performed by a cut-down on the vas and introducing a canula through which contrast is injected. The technique can be performed by directing a needle into the seminal vesicles transrectally under ultrasound control. This is less invasive. It carries the obvious risk of infection but with suitable antibiotic cover the risk appears to be small.⁴⁵

If a Müllerian duct cyst, or an obstructed ejaculatory duct, is thought to be the cause of obstruction then a cut-down via the urethra may be performed. Transrectal ultrasound guided injection of methylene blue into the structures prior to surgery aids in their identification at urethroscopy.

Radioisotope imaging

Radioisotope imaging is used in the urogenital tract mainly to obtain physiologic information. The relative function of both kidneys can be assessed. The emptying pattern of both pelvicalyceal systems can also be assessed in cases of possible obstruction, in particular, to distinguish cases of pelviureteric junction obstruction with significant obstruction from those without^{46,47} (Figure 1.27).

Antegrade and retrograde pyelography

Antegrade pyelography is now almost exclusively used in the insertion of nephrostomy drains and ureteric stents rather than for primary diagnostic reasons.

The diagnostic information formally obtained by diagnostic antegrade or retrograde pyelography is now most often obtained by CT. Both techniques do still

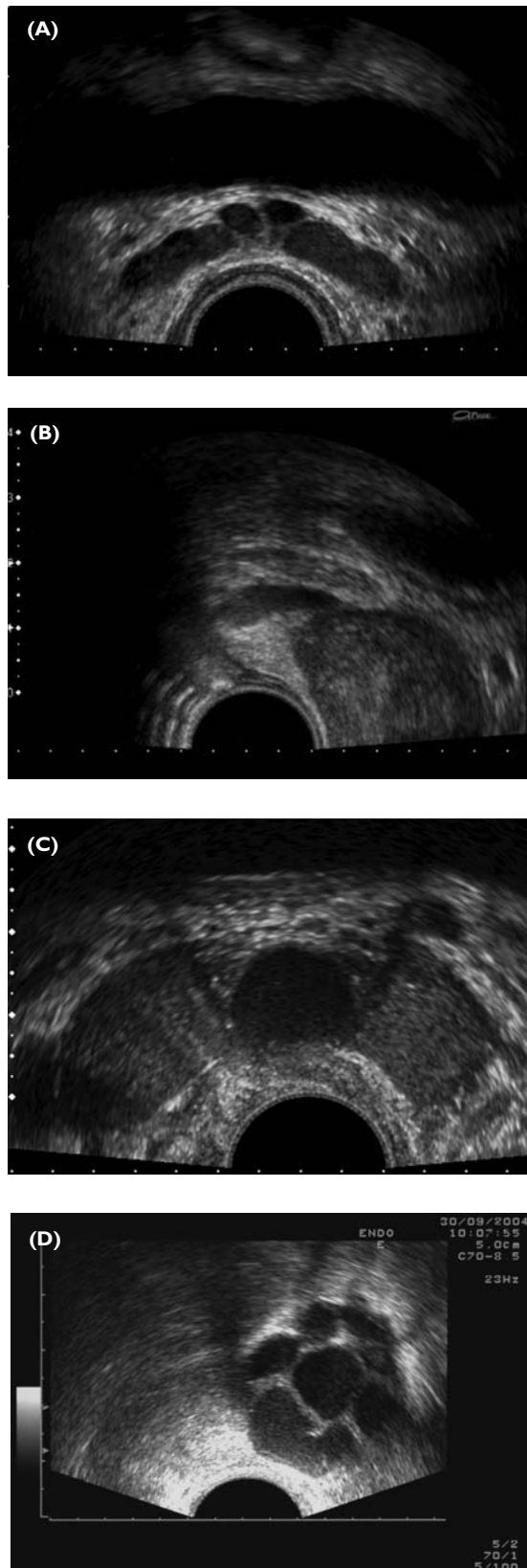


Figure 1.25 Transrectal ultrasound infertility study. (A) Axial view of the seminal vesicles laterally and a normal vasa deferentia medially. (B) Oblique sagittal view of the left vas entering the prostate. (C) Axial view of a Müllerian duct cyst. (D) The same case. Dilated seminal vesicles, obstructed by the cyst.

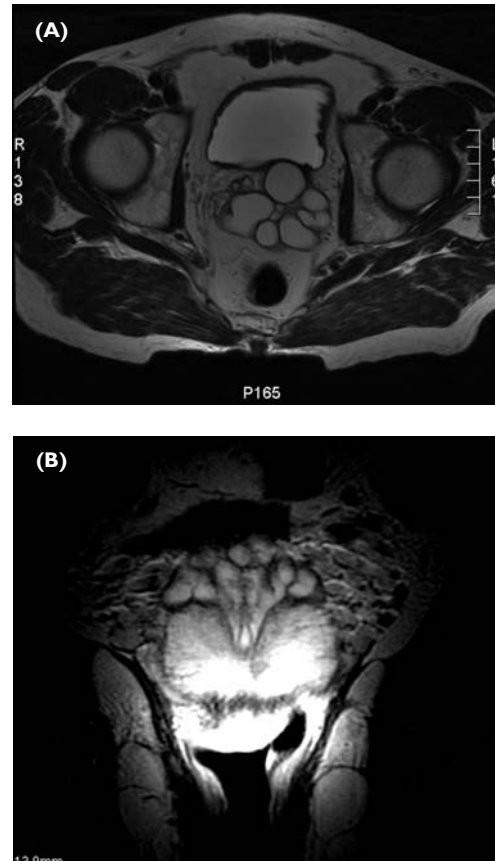


Figure 1.26 MRI study in infertility. (A) Axial view of the dilated obstructed seminal vesicles. (B) Coronal view of the vasa deferentia entering the prostate.

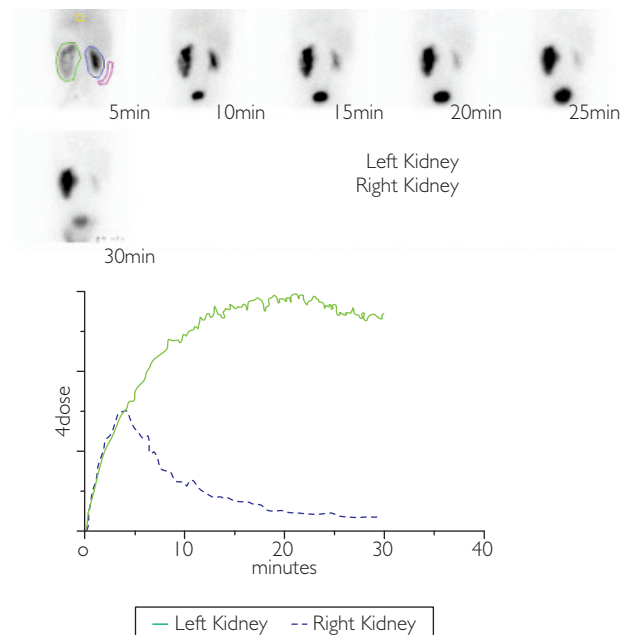


Figure 1.27 Radionuclide study. This shows the use of a radionuclide study in renal physiology. In this case a mag 3 renogram Tc^{99m} mercapto acetyl triglycerine shows an obstructed left kidney.



Figure 1.28 Retrograde pyelogram. This shows how a retrograde pyelogram may still be an excellent way of showing ureteric pathology, in this case a transitional cell cancer.

have a place in a small number of appropriate cases (Figure 1.28).

Cystography

Ultrasound, CT, and MRI have superseded cystography in many cases. The technique retains a role in assessing bladder leaks and vesicoureteric reflux.

Catheter angiography

Diagnostic angiography is now almost exclusively achieved by CT angiography, MR angiography, or a Doppler ultrasound study. Catheter angiography is now mainly used for interventional procedures such as embolization or angioplasty. A selective catheter angiogram will still provide far finer detail of small vessels than any other technique (Figure 1.29).

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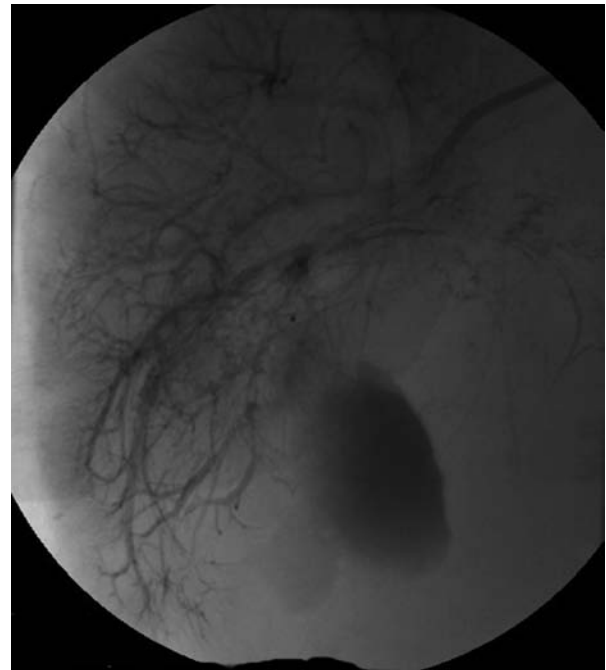


Figure 1.29 Catheter angiogram. This was part of a procedure to embolize the large pseudoaneurysm shown in the lower part of the image. It demonstrates the very fine detail in the small vessels which is far superior to either a CT or an MR angiogram.

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2 Biologic adhesives and hemostatic agents

Keith L Lee and Marshall L Stoller

INTRODUCTION

The use of biologic adhesives and hemostatic agents in surgery dates back nearly a century when Bergel first described using dry plasma for hemostasis in 1909.¹ Over the ensuing decades, fibrin patches, sealants, and glues became available as surgical adjuncts for operative hemostasis and/or tissue adhesion. However, due to concerns regarding viral disease transmission, the US Food and Drugs Administration (FDA) revoked the use of pooled human fibrinogen products in 1978. Not until 1998, with improved sterilization methods, did commercial fibrin compounds re-enter the US market. Within the past 50 years, topical gelatins, oxidized cellulose, microfibrillar collagen, glutaraldehyde compounds, recombinant human factor VII, and others have become available. Urologic surgeons have seen an explosive growth of effective biologic adhesives and hemostatics for open, endoscopic, and laparoscopic surgery. Nevertheless, we must be mindful that the use of these compounds for the most part remains 'off-label' in urology. Moreover, these compounds have similar names yet different mechanisms of action with specific indications and contraindications. Thus, the reconstructive surgeon must have a clear understanding of each compound before using it in surgery.

In this chapter, we review the coagulation cascade and fibrinolytic pathways as they relate to these compounds. We focus our attention on the mechanism of action, product composition, product preparation, optimal application methods, costs, urologic applications, and contraindications to use. We first review purely hemostatic agents followed by compounds with both hemostatic and adhesive properties.

COAGULATION CASCADE

A review of the coagulation cascade and fibrinolytic system is necessary in order to appreciate how biologic hemostatics and adhesives work. Simply put, the coagulation cascade is a system of serine proteases and substrates found within tissues and the plasma that work together to form a clot and prevent further blood loss when injury occurs. As depicted in Figure 2.1, the clotting

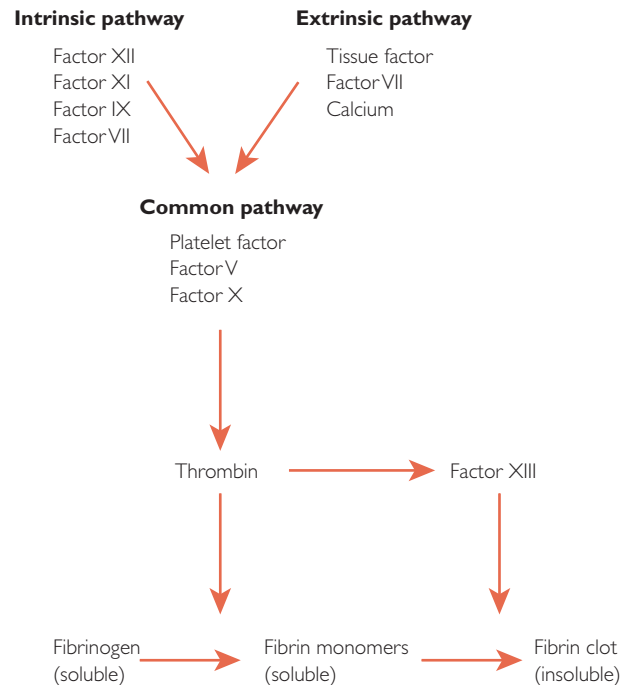


Figure 2.1 The coagulation cascade

cascade consists of an extrinsic and an intrinsic arm. The extrinsic pathway refers to clotting factors found within tissues, and the intrinsic to those found within the circulating plasma. Although depicted separately, the two pathways are interdependent, as activated factor VII promotes the intrinsic pathway. Both pathways lead to activation of the common pathway where platelet factors together with factor X and factor V modify prothrombin into the enzymatically active thrombin. Thrombin then converts fibrinogen into fibrin, the monomeric building block of a clot.

Fibrinogen is a soluble glycoprotein that makes up 0.2% of the whole blood volume.^{2,3} In its non-activated state, it circulates freely in the blood stream. When the coagulation cascade is activated, thrombin will enzymatically cleave the central domain of fibrinogen at fibrinopeptide A and B. After cleavage, fibrin monomers initiate clotting by forming two-stranded fibrils via non-covalent interactions. Covalent cross-linking then occurs between specific glutamine and lysine residues of fibrin molecules by means of fibrin stabilizing factor,

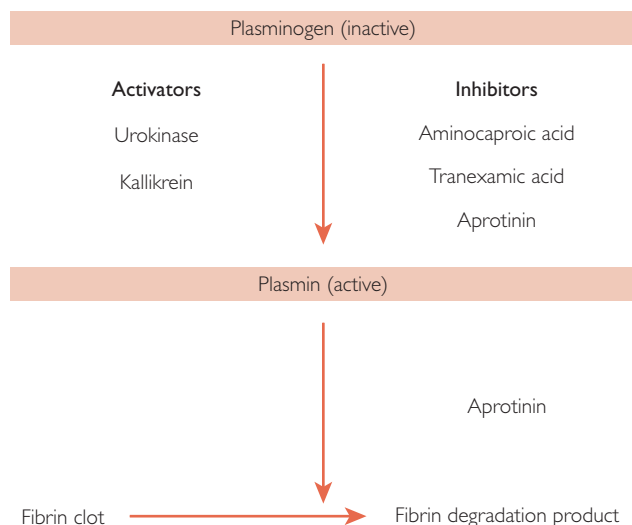


Figure 2.2 The fibrinolytic system and anti-fibrinolytic targets

factor XIII. This cross-linked meshwork of fibrin is insoluble and becomes the clot. Fibrin polymerization and clot formation are calcium dependent, and the rate of clot formation is in part dependent on the amount of fibrin and enzymatic substrates that are locally present.^{4,5} Some biologic adhesives and hemostatic agents rely on endogenous clotting factors while others do not. Furthermore, some compounds are a mixture of proteins that target different pathways of the cascade to work synergistically. Some are human derived, while others are derived from animals or are completely synthetic.

FIBRINOLYSIS AND ANTIFIBRINOLYTIC ADDITIVES

Once the clot is formed, a host of growth factors are released to promote fibroblast ingrowth and subsequent tissue healing. Over a matter of weeks as the wound heals, the fibrin clot must be lysed and degraded. The fibrinolytic system serves this purpose and is shown in Figure 2.2. Plasminogen is converted to plasmin under the stimulation of various activators such as kallikrein and urokinase. Once activated, plasmin breaks down the insoluble fibrin meshwork and clot at specific lysine residue sites.² Biologic hemostatics such as aprotinin, aminocaproic acid, and tranexamic acid target plasmin and the fibrinolytic system. In blocking plasmin, the fibrin clot remains stable.

While antifibrinolytic agents do not initiate clot formation, they are often used as additives along with fibrinogen or gelatin matrix to promote clot stability.

Bovine derived aprotinin is a potent protein inhibitor of several serine proteases in the fibrinolytic system.^{3,6} It directly interferes with plasmin activity and also blocks kallikrein mediated activation of plasminogen into plasmin. However, patients with bovine sensitivity can experience skin rash, coagulopathy, and even anaphylaxis due to preformed antibodies. As alternatives, synthetic amino acids such as 6-aminohexanoic acid (aminocaproic acid) and 4-aminomethyl-cyclohexanecarboxylic acid (tranexamic acid) have been used in place of aprotinin.⁷ These amino acids target the lysine binding sites of plasminogen and plasmin, thus, impairing plasmin activity and fibrin degradation.⁸

STRUCTURAL HEMOSTATIC AGENTS

To promote coagulation and enhance clot formation, structural hemostatic agents are used to ‘trap’ clotting factors in circulation and serve as a mechanical scaffolding for fibrin and clot formation. Once in place, they should not be removed otherwise further bleeding can occur. In addition, this group of agents has no intrinsic adhesive property. They include topical gelatins, oxidized cellulose, and microfibrillar collagen. Compared with other biologic hemostatic agents, this group of compounds is the least expensive (Table 2.1).

GELATINS (Gelfoam®, Surgifoam™)

Introduced in 1945, the prototype in this group is Gelfoam. Gelatin products are derived from porcine gelatin and molded into a sponge. The prepackaged sponge is cut to the desired size and immediately ready for use. There is no other preparatory procedure needed. When bleeding is encountered, the gelatin sponge is applied topically, where it will adhere to tissue. Pores in the gelatin will trap platelets and initiate the coagulation cascade and clot formation. Thrombin, derived from bovine sources, can be added before use to facilitate clot formation. Once thrombin is applied or when the sponge becomes wet, it is more difficult to handle and can break off into smaller pieces. When placed onto tissue, direct pressure can be applied onto the sponge for tamponade. However, the gelatin sponge must be left on the tissue because its removal can remove the clot and lead to bleeding.

In urology, gelatin sponges are most often used in the setting of partial nephrectomy or pelvic bleeding. In open partial nephrectomy, sponges are left in the wedge defect or the cut surface in case of a heminephrectomy. Renorrhaphy is performed over these sponges which act

Table 2.1 Hemostatic and bioadhesive sealants used in urology

Description	Normal clotting required (Y/N)	Sealant property (Y/N)	Product example	Unit cost (\$)
Gelatin	Y	N	Gelfoam [®] , Surgifoam [™]	15–60
Oxidized cellulose	Y	N	Surgicel [®]	25–50
Microfibrillar collagen	Y	N	Instat [®] , Actifoam [®] , Avitene [®] Helistat [®] , Superstat [®]	60–100
Recombination factor VIIa	N	N	NovoSeven [®]	4500
Gelatin matrix and thrombin	Y	N	FloSeal [®]	60–180
Gelatin matrix	Y	N	Surgiflo [™]	90–110
Fibrin sealant	N	Y	Tisseel VH [®] , Hemaseel [™] , Crosseal [®]	170/2 ml* 410/5 ml*
Synthetic sealant	N	Y	BioGlue [®] , CoSeal [®]	1400/2 ml* 2400/5 ml* 3300/10 ml*
Topical sealant	N	Y	Dermabond [®] , Indermil [®]	10–30

*Unit cost given for the first product in this group.

as mechanical bolsters. In laparoscopic partial nephrectomy, pre-cut sponges soaked in thrombin are first placed into the finger pocket of a surgical glove.⁹ The entire unit is then delivered through a 10 mm laparoscopic port. The sponges are retrieved laparoscopically and used in a similar manner. Gelatin sponges can also be placed on top of other bleeding surfaces as long as the bleeding is not brisk. They may be useful in the renal bed after nephrectomy when the psoas sheath is stripped. They can also be used in the pelvis or along the pelvic side wall after resection of locally invasive diseases of the prostate or bladder.

When using gelatin sponges it is important to remember that they depend on the patient's coagulation cascade. Those with coagulopathies will not benefit from gelatin sponges alone. In addition, there are patients who have certain religious beliefs that make this product theologically unacceptable. It is the surgeon's duty to address these issues with the patient before surgery.

OXIDIZED CELLULOSE (Surgicel[®])

Surgicel became available in 1960. Derived from plant material, pure cellulose is knitted into gauze and oxidized. Surgicel is pliable and easy to handle, and unlike gelatin sponges, Surgicel gauze can be folded over irregular tissue shapes without breaking and can also be rolled into cigarette-like sponges. There is no preparatory step necessary prior to use. When placed onto bleeding surfaces, blood and clotting factors are trapped between the microfibers of the gauze, leading to fibrin and platelet aggregation. Its uses are similar to

those of gelatin sponges. In laparoscopic partial nephrectomy cases, pre-rolled Surgicel 'cigarettes' can be delivered through the 10 mm port with ease and used as a mechanical bolster on the cut renal surface.¹⁰ Its pliability also makes it useful as a cover over bleeding renal surfaces where the renal capsule may have been torn.¹¹ Once in place, the gauze should be left undisturbed to avoid disruption of the clot. Again, as a structural hemostatic agent, the patient must have an intact coagulation cascade for Surgicel to work. Surgicel does not have any sealant property and is not effective in sealing percutaneous nephrostomy tracts in tubeless percutaneous nephrolithotomy cases.¹²

MICROFIBRILLAR COLLAGEN (Instat[®], Actifoam[®], Avitene[®], Helistat[®], Superstat[®])

Compounds in the microfibrillar collagen group are derived from purified animal collagen and processed into microcrystals that are less than a micron in size. For example, Instat is derived from bovine corium and packaged as a dry and fluffy powder that can be used immediately. There is no preparatory step prior to use on bleeding surfaces. Microfibrillar collagen is also available as a sponge and a non-woven web (Actifoam and Avitene, respectively). Similar to gelatins and cellulose, collagens serve as a scaffolding for circulating fibrinogen and platelets in blood where it initiates the patient's intrinsic coagulation pathway. Platelet activation also occurs via the thromboxane A2 pathway, and some have found collagens to be slightly more effective than gelatins and cellulose.^{13–15} Once the clot begins to form,

the collagen should be left undisturbed to minimize further bleeding. Collagen compounds are biodegradable and are reabsorbed in 8–10 weeks. Unlike gelatin and cellulose, collagen powders have limited application in laparoscopy due to difficulty in delivery. In open urologic surgery, collagen can be useful for diffuse venous bleeding from the pelvic side wall or from renal surfaces.

RECOMBINANT FACTOR VIIa (NovoSeven®)

Factor VIIa is important to clot formation in both the intrinsic and extrinsic coagulation cascade. In the critical care and trauma literature, recombinant factor VIIa has been shown to decrease blood loss, minimize transfusions, and improve overall clinical outcomes.^{16,17} This hemostatic agent is extremely expensive, and, to date, experience in urology has been limited to prostatectomy. In a double-blind, randomized, placebo controlled trial of 36 men, investigators found that factor VIIa decreased blood loss and blood transfusions in a dose-dependent manner.¹⁸ Side-effects and adverse events have not been critically examined due to small sample size. Nevertheless, this hemostatic agent may be life-saving when massive hemorrhage is encountered.

GELATIN MATRIX WITH THROMBIN (FloSeal®, Surgiflo™)

The prototype in this group is FloSeal, a viscous hemostatic matrix that became available in 1999. It consists of human derived thrombin and bovine derived gelatin matrix microgranules cross-linked with glutaraldehyde. Prior to use, pre-packaged thrombin powder must be reconstituted with 5 ml of calcium chloride solution. Once in solution, thrombin is placed into a syringe and adapted to a female Luer connector that is pre-attached to a second syringe containing the proprietary gelatin matrix. The plunger of the thrombin solution is then pushed to deliver thrombin through the Luer connector and into the syringe containing the matrix. The plunger is then returned, and the process is repeated 20 times for proper mixing. Once prepared, FloSeal should be allowed to sit for an additional 30 seconds for optimal consistency, and it should be used within 2 hours of mixing. The entire preparatory process takes about 5–10 minutes in experienced hands. Occasionally, the Luer connector can become clogged and when not properly seated, the matrix or thrombin can spill during

mixing. Surgiflo is similar, using a proprietary porcine derived gelatin matrix that must be mixed with thrombin prior to use. Thrombin is not pre-packaged, and this allows for custom mixing. Higher concentrations of thrombin can be used, and this should lead to enhanced conversion of fibrinogen to fibrin during clot formation.

Gelatin matrix with thrombin is applied through straw-like applicators of different lengths depending on the type of surgery performed (e.g. laparoscopic, percutaneous, or open). Once in contact with tissue and blood, endogenous fibrinogen is activated within the matrix and coagulation begins. The gelatin matrix microgranules will conform to irregular tissue surfaces and swell 10–20% within 10 minutes and provide some local mechanical compression. Due to the fact that FloSeal and Surgiflo require endogenous fibrinogen to work, the matrix should be applied directly onto bleeding surfaces of the surgical defect. Excess granules that are not incorporated into the hemostatic clot should be removed by gentle irrigation. Incorporated granules are biodegradable and are reabsorbed over 6–8 weeks.

In urology, gelatin matrix with thrombin is often used in nephron-sparing surgery to help decrease blood loss. In small case series where exophytic renal tumors were excised, gelatin matrix alone can achieve excellent hemostasis.¹⁹ When tumor locations require deep resections, gelatin matrix can be used as an adjunct to minimize bleeding and operative complications. Mechanical bolsters such as Gelfoam or Surgicel when necessary in deep resections, should be placed on top of the gelatin matrix prior to suture renorrhaphy.^{10,20} Gelatin matrix with thrombin also has been used to seal percutaneous tracts through the kidney in tubeless percutaneous nephrolithotomy cases with success.^{21,22} It is important to note that gelatin matrix should be placed in the renal defect only and not in the subcutaneous tissue or near the skin because the latter can delay skin healing and increase infectious risks. In urine, FloSeal becomes a fine colloidal suspension.²³ While small amounts of FloSeal injected inadvertently into the collecting system should pass and may not be of clinical significance, some surgeons will place a retrograde ureteral occlusion catheter up to the percutaneous tract on the collecting system side to minimize antegrade flow of FloSeal during application.²² There is also limited experience with FloSeal application along the neurovascular bundles during robotic radical prostatectomy for improved hemostasis.²⁴ Finally, in renal trauma models, FloSeal has been shown to minimize blood loss and effectively shorten the time to hemostasis when applied to injured renal tissue.²⁵

Despite its name, FloSeal is not a strong sealant, and this class of hemostatic agents will not seal defects of the urinary system without a significant bleeding source. There is no intrinsic tissue adhesive property, and they should not be used as sealants for ureteral anastomosis for example. Thus, they should be viewed more as hemostatic agents. FloSeal and Surgiflo must not be applied directly into blood vessels due to risks of intravascular clotting. The bovine component in FloSeal can cause a hypersensitivity reaction in some patients, and despite careful sterilization processing, there is always a theoretical risk for viral or prion transmission from use of human derived thrombin. Finally, the surgeon must remember that gelatin matrix with thrombin is an adjunct to and not a substitute for meticulous surgical technique. Collecting system defects as well as large renal end vessels encountered in nephron-sparing surgery still require suture repair.

FIBRIN SEALANT (Tisseel VH®, Hemaseel™, Crosseal®)

The agents described so far all require endogenous fibrinogen to work. As a result, their hemostatic efficacies are limited in patients with coagulopathies. The solution of course is to deliver exogenous fibrinogen together with thrombin and other pro-clotting factors directly onto the site of injury. By bringing together all the substrates necessary for clot formation in the final steps of the common coagulation pathway, the surgeon can achieve hemostasis even in coagulopathic patients. The first use of human fibrinogen and thrombin was as early as 1944.²⁶ However, preparation techniques were cumbersome and often with unpredictable yields. In addition, sterilization procedures were rudimentary, raising concerns for blood-borne disease transmission by the FDA. It was not until 1998 with the introduction of Tisseel VH, that the use of fibrin sealant took hold in the US.

Tisseel VH (also marketed as Hemaseel) is the prototype in this category of hemostatic agents. It is packaged in separate vials and must be prepared in two separate syringe containers prior to use. One solution contains highly concentrated human fibrinogen, fibronectin, factor XIII, and bovine aprotinin. The concentration of fibrinogen is supraphysiologic, and this allows for a large and robust clot to form upon activation by thrombin. Fibronectin is added to promote fibrin cross-linkage as well as cellular migration of fibroblasts.^{2,27} Factor XIII as discussed earlier stabilizes

the fibrin meshwork via covalent cross-linkage of fibrin monomers, and aprotinin is an anti-fibrinolytic added to promote clot stabilization. The second solution contains highly concentrated, bovine thrombin suspended in a calcium chloride. This second solution serves as the enzymatic catalysis for rapid conversion of soluble fibrinogen into the insoluble fibrin clot.

The two solutions are prepared and heated for 30–40 minutes prior to use. To deliver the fibrin sealant, a dual chamber syringe adaptor system is used where the two solutions are injected at roughly the same rate onto tissue via a Y-adaptor. Applicators come in different lengths to facilitate laparoscopic and endoscopic uses. A fine mist spray delivery system also exists and can be useful in covering a large surface area. Mixing of the two solutions leads to rapid and near immediate conversion of soluble fibrinogen to a viscous and tacky fibrin coagulum. Clot formation is complete within 3 minutes. This clot is biodegradable and reabsorbed over 2–4 weeks without fibrosis or foreign body reaction.

To avoid clot formation and clogging within the applicator tip, the surgeon should use continuous forward pressure when applying the sealant. Also, each syringe must be carefully seated and secured in the dual chamber syringe adaptor prior to use otherwise spillage and premature clot activation can occur outside of the surgical field. Given the long preparation time, spilled sealant or a clogged adaptor tip can be suboptimal when unexpected bleeding is encountered and fibrin sealant is urgently needed.

Fibrinogen in fibrin sealant is derived from pooled plasma donors and purified using advanced fractionation techniques. The final product is a highly concentrated and uniform preparation of fibrinogen. To minimize the likelihood of disease transmission, donor screening, serum testing, re-testing after 90 days of storage, and a two-step vapor heating sterilization process are used.²⁸ While the risk of blood-borne disease transmission may never be completely eliminated, to date, there has been no documented disease transmission from the use of FDA-approved fibrin sealants. The proven safety and reliability of pooled donor fibrinogen has largely replaced the use of single and autologous donor fibrin preparations because the latter two methods are time-consuming and yields can be unpredictable. Nevertheless, prior to the FDA's approval of fibrin sealant from pooled donors in 1998, single donor methods were more commonly employed in the US.³

Introduced in 2003, Crosseal is a similar product that is entirely human based. Both fibrinogen and

thrombin are derived from pooled donor plasma. To minimize transmissible pathogens, this product undergoes additional sterilization procedures such as thrombin nanofiltration, fibrinogen heat pasteurization, and solvent detergent washes. In place of bovine aprotinin, synthetic tranexamic acid is used as the antifibrinolytic. Although bovine sensitivities are avoided, tranexamic acid has been associated with neurological side-effects in animal models.²⁹ Crosseal is contraindicated where cerebral contact may occur, and it may be wise to avoid its use near nerve roots and the spinal column.

While fibrin sealant is FDA approved for uses in pulmonary bypass, splenic injury, and colostomy closure, 'off-label' urologic applications are myriad and can be categorized broadly into hemostatic and tissue adhesion. Most clinical and experimental data regarding fibrin sealant's hemostatic efficacy come from renal surgery. In laparoscopic nephron-sparing surgery, where intracorporeal suturing can be time-consuming and technically difficult, some surgeons have replaced suturing with direct application of fibrin sealant to the tumor resection bed.^{20,30} So long as the depth of resection is less than 5–10 mm and where the collecting system and renal sinus are not entered, clinical and experimental data have demonstrated effective hemostasis with minimal postoperative complications. In case of deep renal resections, fibrin sealants alone may not be sufficient, and animal data have demonstrated hematoma formation underneath the fibrin clot.³¹ To avoid such complications, FloSeal application to the cut surface followed by fibrin sealant is effective. Fibrin sealant can also be used with surgical bolsters such as thrombin-soaked Gelfoam or rolled up Surgicel 'cigarettes' in the form of a 'sandwich' where the sealant is applied both deep and superficial to the bolster.³² In our experience, we have found that the combination of Floseal and suture renorrhaphy over a Gelfoam bolster to be highly effective and generally sufficient. On rare occasions where bleeding continues, the adjunctive use of fibrin sealant can be highly effective. Within several minutes, the fibrin sealant is set, and perhaps due to its biologic nature, the clot adheres well to tissue and is not easily disrupted.

Other primary hemostatic uses of fibrin sealant have been described in renal trauma where fibrin sealant is applied as a thin coat over the renal surface for hemostasis.³³ In tubeless percutaneous nephrostomy cases, fibrin sealant has been effective in maintaining hemostasis as well as sealing of the collecting system.³⁴ Investigators have used postoperative computed tomography imaging to confirm the absence of perinephric hematomas. For such tubeless cases, 2–3 ml of sealant is

applied under endoscopic guidance as the nephroscope is withdrawn.³⁵ The surgeon must inject the sealant carefully onto the renal tract only and not into the collecting system. Experimental models have shown that fibrin sealant becomes a solid clot when injected into urine, and it maintains a semi-solid state for at least 3–5 days.²³ If there is any concern regarding possible urinary tract obstruction from injected fibrin sealant in the collecting system, a ureteral stent and Foley catheter should be placed. Finally, fibrin sealant has been used to control bleeding in coagulopathic patients with hemorrhagic cystitis refractory to endoscopic fulguration³⁶ and in patients with hemophilia after circumcision.³⁷

Unlike the hemostatic agents previously described, fibrin sealant has a tacky physical property, and the activated fibrin coat or clot will 'stick' to tissue. It is this property that makes it effective as a tissue sealant. In partial nephrectomy cases when the collecting system is entered, fibrin sealant has been shown to strengthen traditional collecting system repair, increasing suture-line bursting strength.^{38,39} Fibrin sealant also has been used to reinforce ureteral anastomosis in ureteral surgery and laparoscopic pyeloplasty.^{28,40} The added security and strength of the fibrin seal has led some surgeons to go 'drain-free' without compromising clinical outcomes. Nevertheless, it is important to remember that fibrin sealant is an adjunct and does not replace meticulous surgical technique.

Elsewhere in the urinary tract, fibrin sealant has been applied successfully to both simple retropubic and radical retropubic prostatectomy.^{41,42} Fibrin sealant is applied over the sutured capsulotomy in the former and over the urethrovesical anastomosis in the latter. In the former group, patients left drain-free were shown to have a faster recovery with shortened hospital stay. In the latter group, drain output was significantly lower. More distally in the urinary tract, fibrin sealant is extremely effective both as a sealant and as a tissue bioadhesive for reconstructive urethral surgery.^{28,43} Applied as a thin coat over suture lines, fibrin sealant can strengthen repair, facilitating healing, and allow for earlier catheter removal. There are data to suggest enhanced tissue healing and angiogenesis with fibrin sealant, perhaps due to the stimulatory effects of fibronectin in fibrin sealant preparations.

In the male reproductive tract, fibrin sealant has been used in vasovasostomy and vasoepididymostomy to reinforce suture lines and shorten operative time.^{44,45} In small case series, single layer sutured anastomosis with fibrin sealant was as effective as traditional two-layered closures. Long-term clinical results are lacking and until more is known, fibrin sealant should remain

as an adjunct to traditional suturing techniques. Fibrin sealant also has been tested in orchiopexy to obviate the need for transtunical sutures.^{46,47}

Fibrin sealant is useful for securing skin grafts in penile, scrotal, and perineal reconstruction.²⁸ A thin layer of the sealant is applied to the graft bed, followed quickly by placement of the graft onto the sealant. It is important to fix the graft in place before the sealant 'sets' because the fibrin clot then becomes a barrier rather than an adhesive. Fibrin sealant can eliminate dead space between graft and graft bed where hematoma or seroma can form. Graft motion is minimized once the fibrin sets, thus allowing for earlier revascularization and healing.

Surgeons also have reported success with fibrin sealant in closure of urinary fistula. Applications range from vesicovaginal, ureterovaginal, vesicoperineal, colovesical, nephrocutaneous, as well as cutaneous fistula to a neobladder.⁴⁸⁻⁵¹ Fibrin sealant can be applied with an endoscopic applicator and is minimally invasive compared with more definitive open repairs. It is important to note that most reports contain small numbers.

Contraindications to use of fibrin sealants are similar to Floseal and other agents that contain concentrated thrombin. Direct application into open blood vessels must be avoided because of risk for intravascular clot formation. Compounds containing bovine derived factors should not be used in patients with documented bovine hypersensitivities. Also, fibrin sealants should not be used in patients with religious beliefs against use of animal and human derived products.

SYNTHETIC SEALANTS FOR INTRACORPOREAL USE (BioGlue®, CoSeal®)

In an effort to completely eliminate the risk of transmissible diseases from donor derived products, synthetic sealants have been developed. In general, there is minimal set-up time, and the compounds can be used almost immediately from package to patient. The major drawback for synthetic sealants is that some tend to be poorly biodegradable, and others can be associated with increased foreign body reaction. They also tend to retain their semi-solid form in urine and can put patients at risk for urinary tract obstruction should they enter the collecting system. Further, these compounds are quite new to urology, and there are few data on safety and long-term efficacy.

BioGlue is a two-component adhesive that is delivered in a similar manner to fibrin sealant. One vessel contains synthetic glutaraldehyde, and the other contains purified bovine serum albumin (BSA). Upon mixing, glutaraldehyde covalently cross-links BSA molecules together, forming an artificial clot that is independent of the coagulation cascade. BioGlue has been shown to be quite effective in sealing anastomoses in vascular and cardiac cases. Cross-linkage between BSA and the patient's tissues occurs at the amine groups of the extracellular matrix. Different applicator tips and extenders are available for open and laparoscopic use. Technically, successful application requires a relatively dry surgical field. In nephron-sparing surgery where this may not be possible, we have observed that the BioGlue clot does not always remain adherent to the renal defect. Once polymerized, BioGlue is reabsorbed slowly over 3 months. The polymerized clot is quite firm and has a 'plastic' feel to it. In cases of collecting system violation, BioGlue clot may cause urinary tract obstruction. Until more data and clinical experience are available, BioGlue should not be used as a sealant for tubeless percutaneous nephrolithotomy for this reason.

Hydrogel tissue sealant or CoSeal is a completely synthetic sealant that is free of both human and animal proteins. It is made up of two polyethylene glycols (PEGs), a hydrogen chloride solution, and a sodium phosphate/carbonate solution. Delivery is similar to BioGlue and fibrin sealants where reconstituted PEGs are housed in one syringe and the activating solution is housed in the other. When the two solutions mix, polymerization occurs as a result of changes in pH. A flexible, gel-like substance is formed almost immediately. Similar to fibrin sealant application, continuous forward pressure ensures that the applicator tip does not become clogged as the artificial clot forms. Over the next 24 hours, this gel will swell up to four times its volume. Thus, CoSeal should not be applied to areas that are sensitive to compression. Its function as a sealant and adhesive appears to be inferior to fibrin sealant. In a partial nephrectomy animal model, CoSeal did not adhere well to the renal parenchyma and was less effective in sealing urinary tract defects.⁵² There is also concern regarding increased bowel adhesions with this compound compared with fibrin sealant. Finally, in vitro urine exposure studies have shown that the CoSeal clot does not dissolve and remains as a solid after 5 days.²³ Should such a clot enter the collecting urinary system, obstruction is certainly possible.

SYNTHETIC SEALANTS FOR TOPICAL USE (Dermabond®, Indermil®)

Cyanoacrylate adhesives are completely synthetic and poorly biodegradable compared with the other compounds discussed previously. Thus, application in urology is limited to external topical uses such as for closure of laparoscopic port sites after placement of subcuticular sutures. Dermabond (2-octyl-cyanoacrylate) and Indermil (n-butyl-2-cyanoacrylate) are supplied in the form of a soluble liquid monomer in a self-contained clear applicator. Fine applicator tips are available for improved delivery control. Once the vial is opened, Dermabond must be used immediately as cyanoacrylate polymerization can sometimes clog the applicator tip. Indermil comes with a re-sealable cap and does not have to be used immediately or at the same setting once the vial is opened. When either compound comes into contact with tissue, polymerization and hardening begins instantaneously. The polymerization process takes between 30 and 45 seconds. The resultant polymer is water insoluble and adheres tightly to the skin surface. This hardened film acts as a barrier to bacteria, and will stay on the wound for 5–7 days. These compounds have advantages over traditional surgical dressings in pediatric hypospadias repairs because the liquid conforms to irregular surfaces before setting and is much less bulky. The liquid dressing also does not require subsequent removal, thus minimizing parent and patient anxiety. During application, it is critical to first ensure good tissue apposition because when liquid cyanoacrylate polymerizes between the wound edges, it becomes a barrier to fibroblast and tissue ingrowth and can delay wound healing. When applied onto the penis, it is also important to avoid spillage of the liquid into the urethral meatus. The liquid vehicle in Dermabond is flammable; thus, electrocautery should not be used near this substance until it is completely set and dry.

CONCLUSION

There are numerous biologic adhesives and hemostatic agents available to the urologic surgeon for 'off-label' use. While primary hemostatic agents such as Surgicel, Gelfoam, collagens, and FloSeal rely on endogenous fibrinogen from a bleeding source and an intact coagulation pathway to work, agents containing fibrinogen such as Tisseel VH and Crosseal will work even in coagulopathic patients. With current sterilization techniques, the risk of blood-borne transmissible diseases with the use of

human derived agents is exceedingly rare but not zero. Synthetic sealants can eliminate this risk; however, they are relatively insoluble in urine and may cause urinary tract obstruction if delivered into the collecting system. As newer biologic hemostatics and sealants come into the market, the urologic surgeon must be critical of the agents' efficacy, safety, biodegradability, and cost.

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3 Principles of microsurgery

Maria Siemionow and Serdar Nasir

HISTORY

Microvascular surgery takes its history from the fusion of two disciplines of surgery: vascular surgery and microsurgery. In 1552 Pare¹ described the first vascular techniques followed by Hallowell¹ in 1759, who successfully sutured a brachial artery lesion. Murphy² described the first vascular anastomosis in 1897; however, in 1902, Alexis Carrel³ described the triangulation method in an end-to-end anastomosis. These techniques were further developed by Carrel's co-worker Charles Guthrie, and Carrel was awarded the Nobel Prize in 1912 for his achievement in vascular surgery and organ transplantation. In 1921, the compound microscope was first used in clinical otology by Nylén⁴ in Sweden. Jacobson and Suarez⁵ in 1960 demonstrated successful microvascular repair of vessels as small as 1 mm in diameter. Replantation became the first clinical application of microvascular surgery. In 1964 Malt⁶ successfully replanted the arm of a 12-year-old boy run over by a train. The first digital replantation was performed by Tamai⁷ in 1965 with use of an operating microscope. The first experimental free composite tissue transplantation included abdominal wall musculature, fascia, mammary gland, and skin, and was made on a dog, based on the superficial epigastric vessels and reported by Krizek et al⁸ in 1965. McLean and Buncke⁹ in 1970 performed the first completely successful free flap operation in a human with use of omentum for a large scalp defect. This operation was followed by transfer of the first composite flap, a groin flap, by Daniel and Taylor¹⁰ in January 1973 and repeated 2 months later by O'Brien.¹¹ In 1964, Kurze¹² was first to use microsurgical techniques for peripheral nerve surgery. Vas deferens anastomosis using microsurgical techniques in urologic surgery started with the pioneering work of Silber et al¹³ in 1977, and since that time many other urologic operations have used microsurgical techniques. Today, microsurgery impacts many specialties in medicine from urology, obstetrics, and gynecology to plastic surgery, laryngology, and neurosurgery.

BASIC CONSIDERATIONS

Any surgeon needs the technical attributes of good hand–eye coordination, space care in handling tissues,

and patience for microsurgical techniques. Robert Acland described some preconditions which are needed before performing anastomosis: a good working environment, good equipment, careful operative planning, comfortable positioning and hand support, access and exposure, proper choice of vessels, and hemostasis.

EQUIPMENT FOR MICROSURGERY

Surgical microscope

The operating microscope allows the magnification to be changed from 2× up to 40× during different stages of surgery. The microscope should be double headed so as to allow the surgeon and the assistant to visualize the same field. The illumination generated brings a clear, sharp visual field without shadows. Ergonomics of microsurgery are very important to successful surgery. The microscope and seat must be comfortable and easily adjustable. The surgeon should sit in a slightly forward-leaning position with feet apart, forming a load-bearing triangle that ends at floor level. The upper extremities must be fully supported to allow them to relax to avoid tremor. This comfort is achieved using forearm support.

Surgical loupes

Some experienced microsurgeons opt to use loupes (3.5–8×) for microanastomosis. Loupes provide portability, decreased operating time, and greater operator freedom, as well as offering a cost advantage over the microscope.

Microinstruments

The instruments necessary to perform microsurgical procedures include no. 5 and no. 2 jeweler's forceps (two pairs), microscissors (one round tipped for dissection and one sharp tipped for vessel cutting), and needle holder with rounded handle, which can be delicately maneuvered between the index finger and the

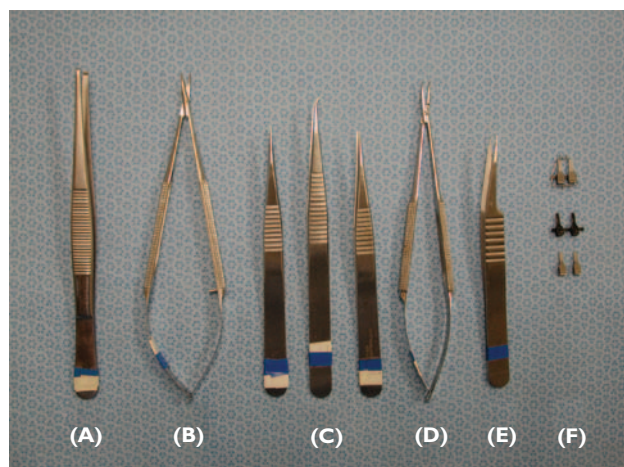


Figure 3.1 Basic set of microsurgical instruments. (A) Clamp applying forceps, (B) microscissors, (C) jeweler's forceps, (D) needle holder, (E) vessel dilator, and (F) approximator and single clamps. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

thumb like a pencil. This set must include approximator clamps and single clamps (Figure 3.1). Additions to the basic set include angled jeweler's forceps, micro-tooth forceps, vessel dilating forceps, and some macro-surgical instruments such as needle holders, Adson forceps, and scissors.

Microsutures

Microsurgical sutures with attached needles have been developed in different sizes and tensile strengths (7-0 to 12-0). The most widely used suture materials in microsurgery are non-absorbable silk, polyamide, and polypropylene. The size of needles varies from 50 to 200 μm , smaller needles are used for venous anastomosis.

BASIC ANASTOMOTIC AND COAPTATION TECHNIQUES

End-to-end anastomosis

Arterial anastomosis

First approximator clamps are placed to hold the two vessel ends for tension-free repair. The approximator clamp easily turns the vessels and permits repair of the back wall after the front wall is sutured. The vessel ends are placed in the approximator clamp and the space between clamps is adjusted to be equal to the vessel's diameter, which avoids vessel tearing due to

excessive distance. Adventitia is removed from vessel ends circumferentially to improve visualization and to avoid inclusion of adventitia into the vessel lumen (Figure 3.2A). Adventitia is very thrombogenic material since it contains collagen fibers and its inclusion into the lumen causes thrombosis. For trimming adventitia, sharp dissection with adventitia scissors is preferred rather than blunt dissection which can result in vasospasm and focal destruction of intima or media. Local irrigation with heparinized saline (5000–50 000 U in 5 ml saline) is accomplished to remove blood from the vessel ends. Before the first suture is applied, vessels ends are dilated by gently using closed dilating forceps or a needle holder inserted to the lumen (Figure 3.2B and C). The needle is grasped one-third beyond the needle–thread junction and microforceps are used to provide gentle counterpressure while the needle penetrates the vessel wall. The aim of microanastomosis is to achieve a leak-proof anastomosis with the smallest number of sutures. The first tie should be double to stabilize conjoint vessel ends, and then one single tie follows to complete the knot. Tightening must be adjusted gently to connect the two vessel ends under vision without tension. Only adventitia is grasped during suture placement. The distance between two sutures and bite size should be equal for successful anastomosis. The vessel is considered as a circle, and the first suture is called the '0° suture' (Figure 3.2D). Following sutures are named according to their location on the vessel circumference. Placing the first suture is challenging due to difficult manipulation of the free vessels' ends and recognition of the vessel circle. Two techniques of vessel anastomosis are used: the 180° halving technique and the triangulation technique. In the 180° halving technique, second suture location is determined at 180° opposite the first suture (Figure 3.2E). The third suture is applied in the middle between the first two sutures (Figure 3.2F). One or two more sutures, depending on vessel diameter, are placed between these sutures to complete the front wall repair (Figure 3.2G). The approximator clamp is then flipped and the first suture on the back wall is placed in the middle (Figure 3.2H). Back wall repair is completed using the same approach as the front wall (Figure 3.2I and J). In the triangulation technique, two sutures (called stay sutures) are placed at 120° apart, creating a longer back wall and a shorter front wall. This lessens the chance of through suturing of the back wall. After placing an adequate number of sutures at the anterior wall, a third suture is placed between the two stay sutures in the back wall and anastomosis is completed with a few extra sutures.

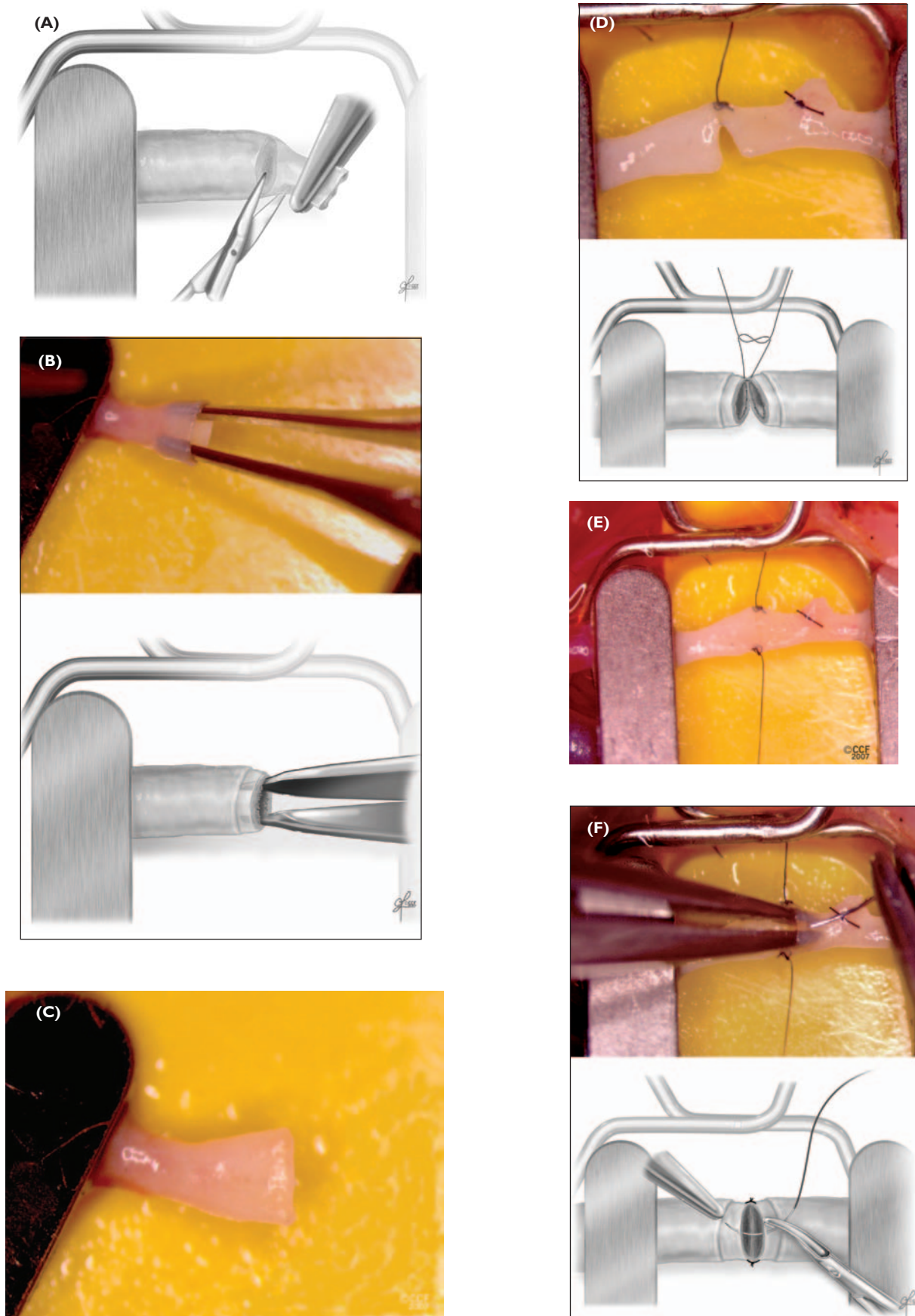


Figure 3.2 (Continued)

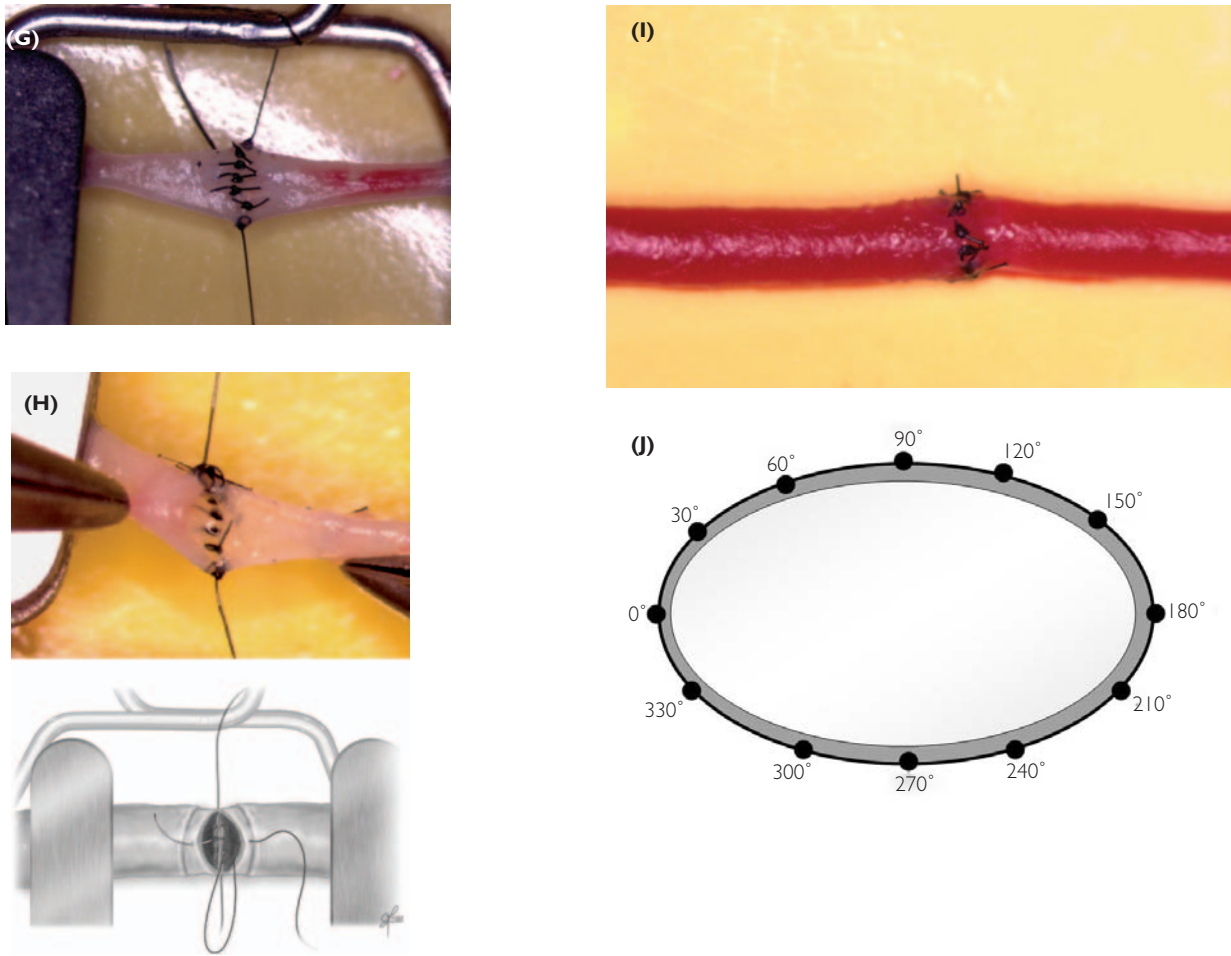


Figure 3.2 End-to-end anastomosis (180° halving technique). (A) Trimming of the adventitia. (B) Dilatation of vessel ends with dilating forceps. (C) Vessel ends after dilatation. (D) 0° suture secured to clamp. (E) Vessel ends are stabilized after second suture (at 180°) (F) Entry of the needle tip with counterpressure into the lumen and out of the vessel. (G) The completed anterior wall anastomosis. (H) Checking posterior wall for the presence of ‘through’ suturing of the back wall by the front wall stitch and sequence of suture positioning (as represented by number in parenthesis). (I) The completed anastomosis. (J) Diagram representing suture locations on the vessel cross-section and followed by placing of the first stitch in the back wall (270°). Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

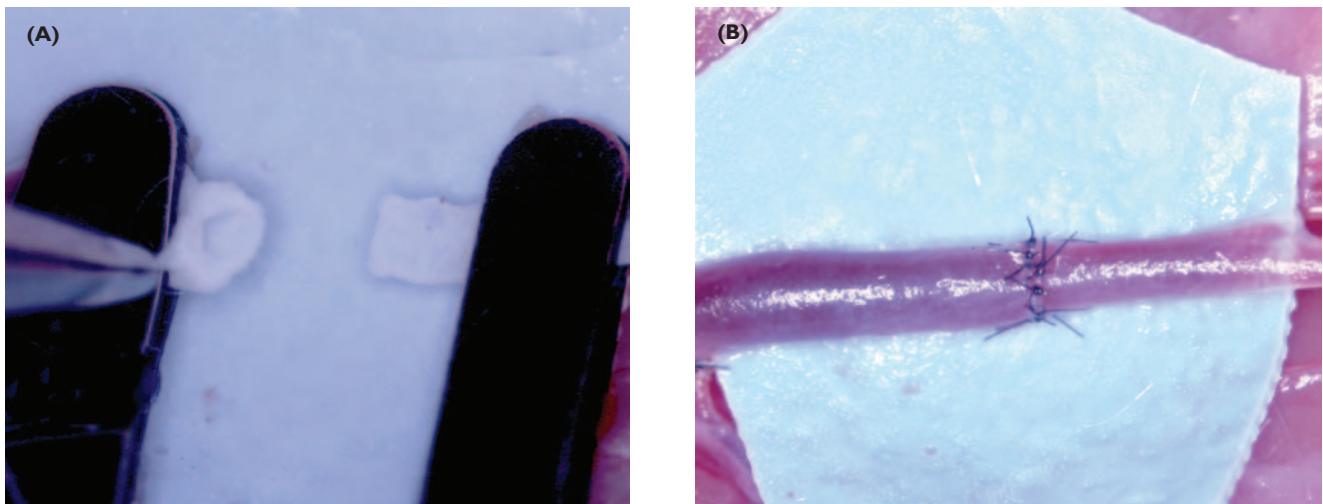


Figure 3.3 Venous anastomosis. (A) Vein ends under the heparinized saline. (B) The completed vein anastomosis. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

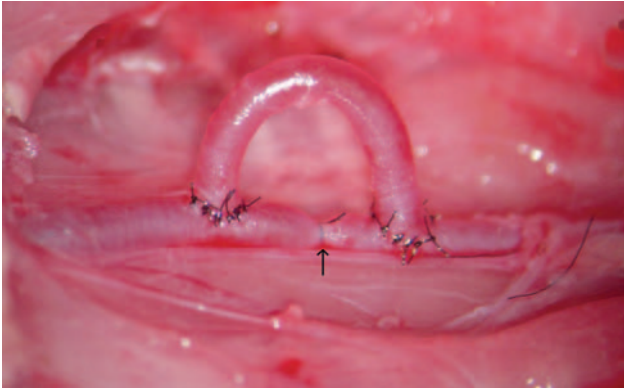


Figure 3.4 End-to-side anastomosis (ETS) model. Femoral or carotid artery grafts are used to bypass carotid artery through two ETS anastomoses. This model is very useful as a training model. Arrow, flow blocking knot to carotid artery. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

If any jet leakage is observed after release of the approximator clamp, the clamp is reapplied and more sutures are placed. Oozing will usually stop after a few minutes, when gentle pressure is applied.

Venous anastomosis

The end-to-end venous anastomosis is done using a technique similar to microarterial repair. The vein structure, with very thin adventitia and thin tunica media due to the lack of a muscularis layer, makes venous anastomosis more challenging. The vessel wall can easily collapse and be injured during anastomosis. Operating 'under water' by flushing the operative field with heparinized saline can help, so that the vein ends are visible and open making anastomosis easier. Adventitia trimming is kept to a minimum to remove superfluous remnants that protrude into the lumen. Determining the plain between tunica adventitia and media is difficult but essential (Figure 3.3).

End-to-side anastomosis

Following approximator clamp application, the first step in end-to-side anastomosis is to create an opening in the front of the recipient vessel wall. This procedure is critical and irreversible and the size of opening must be adjusted according to donor vessel diameter. This is done by plugging 7/0 suture passed through a front part of vessel wall and by excising, via small bite, a piece of vessel wall of elliptical or triangular shape using straight scissors. Next two sutures are placed 180° apart at both corners of the created hole, first in the front wall and then the back wall is completed after flipping donor artery. Sutures are placed from one

corner to the other corner of the vessel as interrupted or by using the 180° halving technique (Figure 3.4).

The assessment of patency of vascular anastomosis

Patency can be assessed 10–20 minutes after the anastomosis is completed. First, the vessel is checked for pulsations distal to the anastomotic site and this is called expansile pulsation.¹⁴ Other tests are the 'uplift test' or 'hook patency test' in which microforceps are placed distal to the anastomosis and gently raised to occlude blood flow. Next, the forceps are moved distally and when blood flow is filling the segment under the moving curved forceps the anastomosis is considered to be patent. In the 'empty and refill' test known also as 'milking test' the distal anastomosis region of the artery is closed with two microforceps. While keeping the most distal forceps closed, a milking motion is performed to empty a vessel segment with the secured pair of forceps. The most proximal forceps are then released and filling of the segment across the anastomosis down to the secured forceps confirms patency (Figure 3.5).

Nerve coaptations

The goal of nerve repair is to align the regenerating axons in such a way as to direct the fibers into the direction of distal nerve end, with minimal loss of regenerating units at the suture line. Vasa nervosum on the extrinsic epineurium are excellent landmarks to line up the nerve for repair (Figure 3.6A). The three surgical techniques of neurorrhaphy in current use are epineurial repair, fascicular repair, and group fascicular repair. Epineurial repair is the standard method of nerve repair, is relatively easy, less traumatic to the nerve ends, and requires less suture material at the repair site. The epineurial repair is performed using 8-0 or 10-0 non-absorbable sutures that are passed only through the epineurium of the nerve ends. First, two sutures are placed opposite each other at 0 and 180° apart and leaving the strands of these two initial knots long may assist in turning the nerve for back wall suture placement (Figure 3.6B). Coaptation should be completed with a minimum number of sutures between four and eight to ensure the proper alignment of nerve ends. The suture should not violate fascicles, and nerve end coaptation should not cause compression at the repair site (Figure 3.6C). In the fascicular group repair, the 10-0 non-absorbable sutures are placed through interfascicular epineurium which covers the fascicular group. This

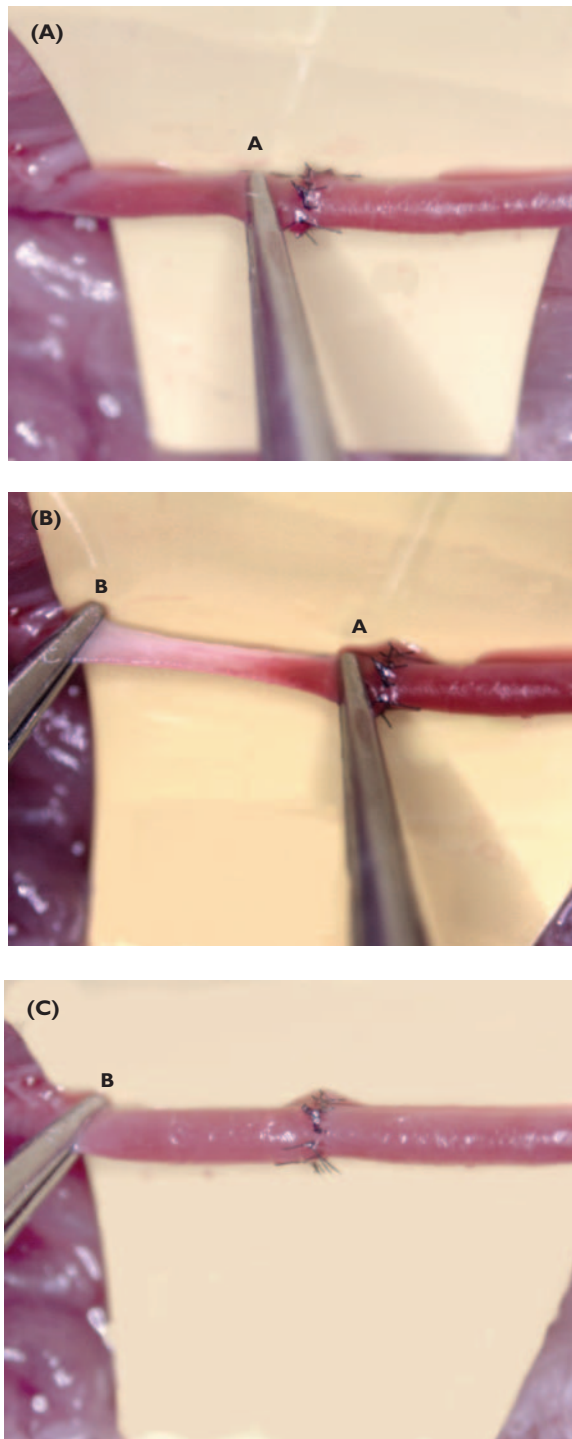


Figure 3.5 Evaluation of vessel patency. Empty and refill test. (A) and (B) Blood flow is secured with forceps 'A' at distal anastomosis site and the blood is discharged by using forceps 'B' using a milking motion from forceps 'A' to the distal region of the vessel. This motion provides emptying of vessel lumen between two forceps. Forceps 'B' are secured to avoid retrograde blood flow into this empty vessel lumen. (C) Forceps 'A' are opened and patency is checked with blood filling into the empty lumen. Successful anastomosis is determining by immediate blood filling. Slow flow segment or no flow indicates anastomosis failure. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

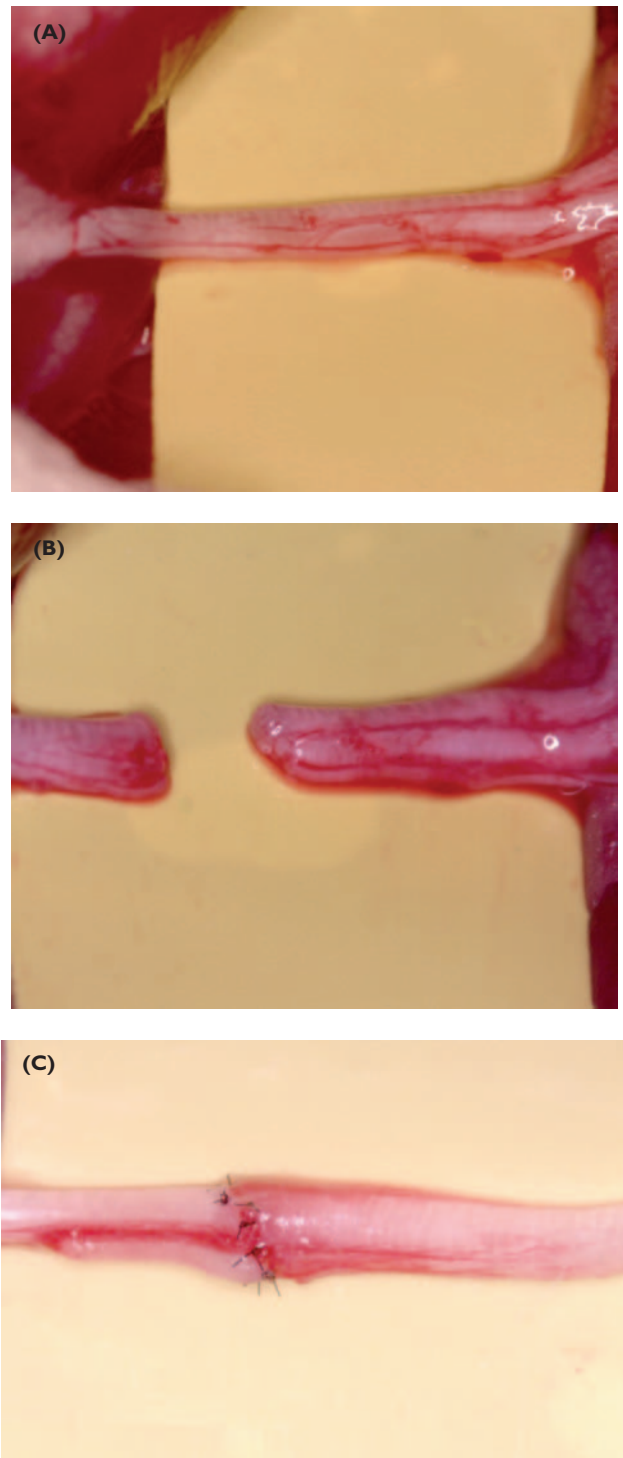


Figure 3.6 Epineural nerve coaptation. (A) Vasa nervorum on the extrinsic epineurium facilitate nerve alignment. (B) Fascicules. (C) The completed nerve coaptation, with realignment of vasa nervorum. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

method should avoid tension, since tension transmitted to individual fascicles leads to ischemia at the repair site. The epineurial layer is then repaired using 8/0 and 10/0 non-absorbable sutures. In the fascicular repair, a single fascicle

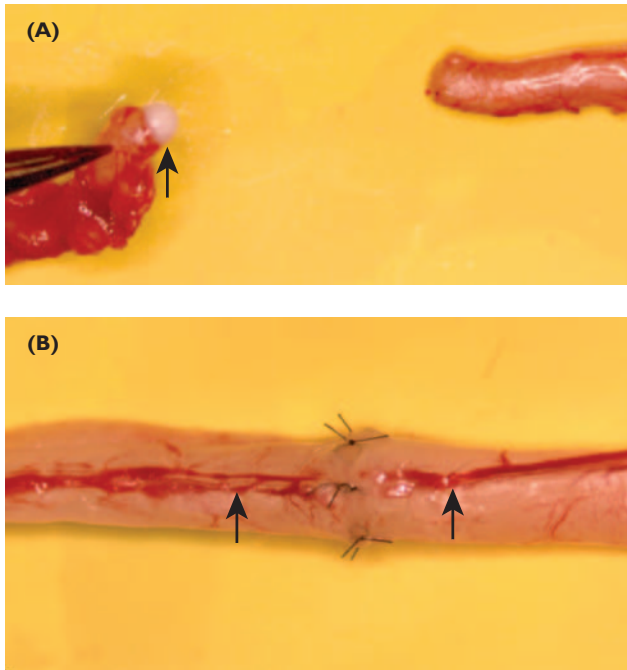


Figure 3.7 Vasovasostomy. (A) After cutting vas deferens, discharged semen from the lumen is observed (arrow). (B) After washing of the ostium, seromuscular stitches with or without mucosal repair are applied as waterproof anastomosis and anastomosis is completed. Arrows, realigned vessels on the vas deferens. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

is repaired only with the two sutures and all tension is avoided. The sutures are passed only through the epineurium with 10-0 or 11-0 suture and nerve repair is completed with a minimal number of epineurial sutures.

VASOVASOSTOMY

In 1903, Martin¹⁵ first reported a surgical procedure to remove obstruction of the vas deferens to restore fertility. In 1977, Silber et al¹³ first reported a technique of direct anastomosis of the mucosa of the vas deferens which led to significant improvements in fertility rates. Vasovasostomy can be applied by two different types of techniques. In the first surgical technique, only a seromuscular suture is placed using 8-0 or 9-0 non-absorbable nylon. First, two sutures are placed at opposite ends at 180°s apart, caring for precise mucosal realignment of two vas ends. One suture is placed between these stitches on each of the front and back wall. Merging mucosal ends allows for a good healing pattern since there is no foreign material used at the anastomosis (Figure 3.7). In the second technique, mucosal repair is done with 10-0 or 11-0 non-absorbable suture applied as the additional seromuscular layer suture. First, two

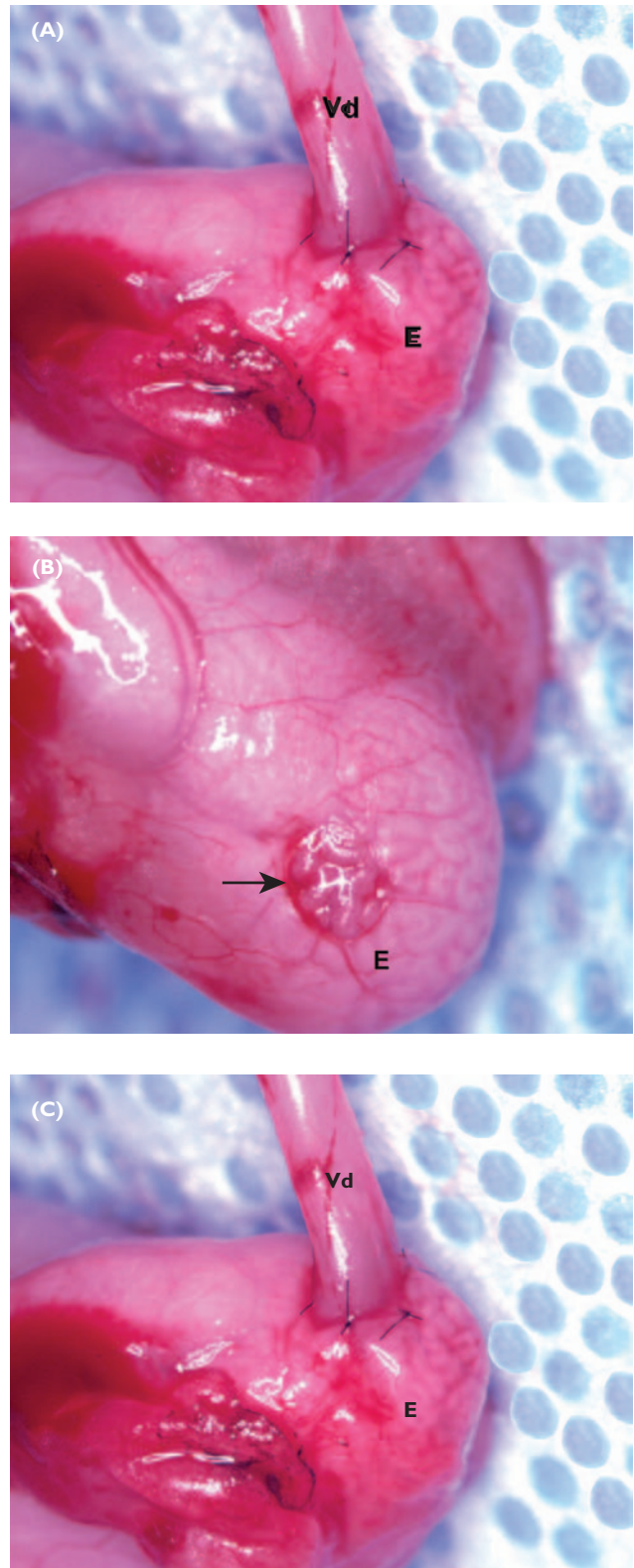


Figure 3.8 Vasoepididymostomy. (A) Preparation of vas deferens and epididymis before repair. (B) Opening window in the tunica vaginalis of the epididymis and view of the discharged fluid. (C) The completed repair. Vd, vas deferens; E, epididymis; arrow, view of window on the tunica vaginalis of epididymis. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

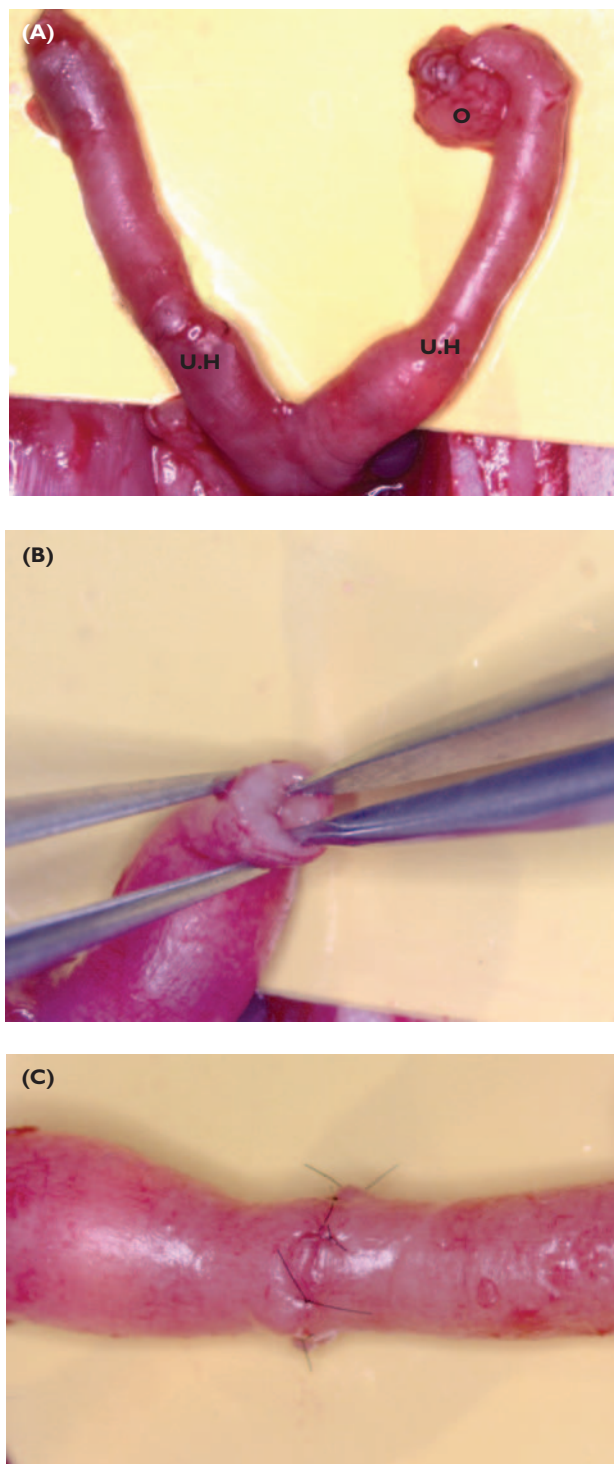


Figure 3.9 Tubatubal anastomosis. (A) Uterine horns of the rat are a suitable model for simulating tubal anastomosis because of similar anatomy to the human ovarian tube. However, the uterine horn of the rat does not include a thick serosal layer which permits repair. (B) Tubal lumen. (C) The completed anastomosis. O, ovary; U.H, uterine horn. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

seromuscular layer sutures are placed similarly like in the first technique but they are not tied and are left loosely.

Four additional sutures are placed for mucosal repair. Two more seromuscular sutures are placed between the first sutures at the front and back wall and all seromuscular sutures are tied to complete the repair.

VASOEPIDIDYMOSTOMY

Epididymal obstruction may require a vasoepididymostomy, and an end-to-side technique is commonly used.¹⁶ After tunica vaginalis of the epididymis is opened, the opening is made in the epididymal wall with the microscissors. Two or three 10-0 nylon sutures are placed posteriorly between the inner layer of the vas deferens and epididymal tubule after checking discharge of fluid from the opened epididymal tubule. After the anterior side is completed, two or three more sutures are applied to the outer layer of the vas deferens using interrupted sutures (Figure 3.8).

TUBATUBAL ANASTOMOSIS

The tubal segments are approximated in two layers. The first repair joins the mucosa and muscularis, and the second repair joins the serosal layer. First, two sutures are placed to the inner musculomucosal layer. The location of these sutures is preferred at the mesosalpingeal border and opposite the site of the first suture to ensure proper alignment of the two segments of tubes using 8-0 suture. Four or five musculomucosal sutures are placed between these sutures at each of the front and the back wall. After musculomucosal repair, the serosa is repaired with either interrupted sutures or continuous sutures applying 7-0 or 8-0 suture material (Figure 3.9).

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4 Principles of tissue transfer

Gerald H Jordan

The term tissue transfer implies the movement of tissue for reconstructive surgical purposes. Therefore, the term distinguishes itself from ablative surgery, where indeed tissue is excised and moved, but for the purposes of elimination of the tissue from the person's body. Thus, imperative to tissue transfer, is the survival of the tissue. This chapter describes the techniques of tissue transfer as they apply to genitourinary reconstructive surgery. In recent years, tissue transfer, as it applies to genitourinary reconstructive surgery, has been a bit of a moving target as better definition and understanding of the principles by which tissues were moved for that purpose have developed. For the most part, tissue transfer for use in genitourinary reconstructive surgery is dependent on graft techniques as well as on local flap techniques. However, an evolution in the understanding of the move from random to axial techniques is based on a number of sentinel studies in which the vasculature to the genitourinary superficial structures was defined.

Inherent to the use of tissue for reconstructive surgical purposes, is the ability to predict how those tissues will behave in the location to which they have been transferred. First and foremost are the tissue characteristics. These include extensibility, inherent tissue tension, and the viscoelastic properties. Extensibility refers to the property of the tissue that allows it to be stretched. It is distinguished from compliance, as compliance infers the ability of tissue to be stretched without increase in inherent tissue tension. Fortunately all human tissues possess extensibility, certainly not all possess compliance. Inherent tissue tension is dependent on the tissue elastin content. For the most part, tissue is a collagen elastin matrix, suspended in mucopolysaccharide. Collagen is arranged in helical strands. These strands are polarized in normal tissue. The loss of polarization equates to loss of extensibility. Collagen for the most part is brittle, its property of extensibility is related to the fact that the collagen helices can be straightened and then ultimately those straightened fibers can slide one against the other. The degree to which those straightened fibers can slide is dependent on the elastin cross members, and the return to normal architecture relates to the architecture of collagen as it relates to elastin. The collagen elastin matrix, as mentioned, is

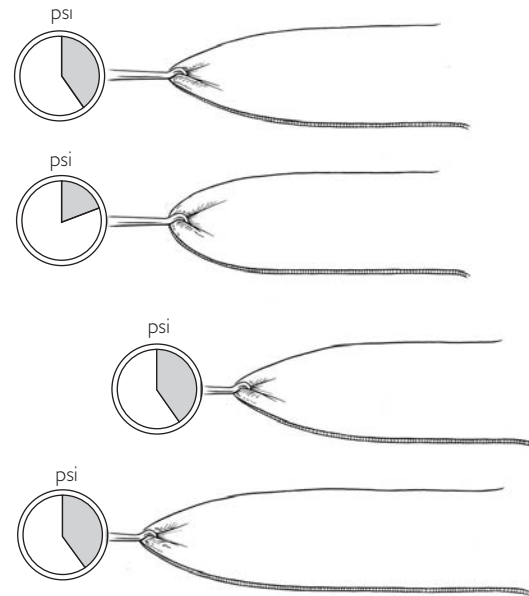


Figure 4.1 Illustration of the viscoelastic properties of tissue. At the top, the tissue is suspended under force. The degree of distension is held constant, the force lessens over time. This is an illustration of stress relaxation. At the bottom, the tissue is distended but the force is kept constant over time. This is an illustration of the viscoelastic property creep.

suspended in mucopolysaccharide. The viscoelastic properties relate to the displacement of the mucopolysaccharide from between the collagen fibers. Two viscoelastic properties have been defined, the property of stress relaxation and creep (Figure 4.1). To understand stress relaxation, one must envision a system in which tissue is distended by force. If the distension of the tissue has remained constant, then over time, the force will decrease; and this is because of displacement of the mucopolysaccharide from between the stretched collagen fibers. On the other hand, if the force is maintained constant, then the tissue will continue to distend, and this property is termed creep. Thus, the viscoelastic properties refer to situations in which the tissue is distended; extensibility and tissue tension are inherent properties and relate to the tissue while static.

The properties of extensibility in tissue transfer can thus be observed by observing the skin as a model. These properties exist for other tissues, but observation of the properties is more difficult in those tissues.

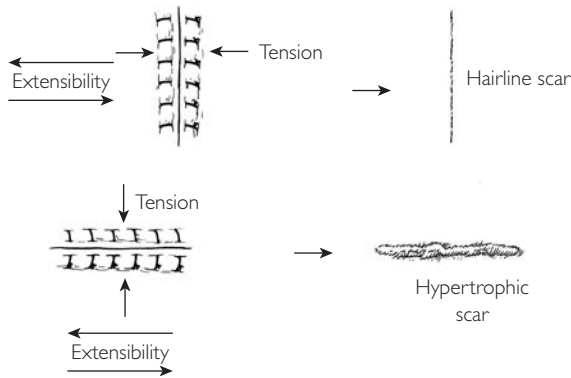


Figure 4.2 At the top, the axis of wound tension is aligned with the axis of maximal tissue extensibility. This creates a hairline scar. If tissue tension is aligned at right angles to innate tissue extensibility as is illustrated in the bottom model, a more hypertrophic scar tends to result. This is an illustration of the principle by which Langer's lines were defined.

Kressel's lines exist overlying the long musculature. Kressel's lines are a reflection of inherent tissue extensibility. Contour lines on the other hand, are those lines which exist as the body changes in contour. For example, the submammary crease would be a contour line. This is a reflection of inherent tissue tension. Over time, with age, inherent tissue tension becomes less; hence, one sees a disappearance, in many individuals, of the submammary crease and the crease at the lower abdomen, which as a defining crease in youth, becomes 'the beer belly' in the older individual. Everyone is familiar with Langer's lines. Definition of Langer's lines exists because of the observation that if one aligns an excisional defect with Langer's lines, one achieves a much finer scar. Thus, Langer's lines are situated at a right angle to the plane of normal extensibility. If one aligns an excisional defect with these lines then the wound would be closed under the least tension, as wound tension aligns with the plane of maximal extensibility (Figure 4.2). Keep in mind that wound tension and inherent tissue tension are not necessarily the same.

If one is going to move tissue, then one must define the unit which is moved. Basically there are two ways of moving tissue, one is as a graft, the second is as a flap. If one chooses to move tissue as a graft then that tissue is excised, moved to a recipient site where that tissue develops a new blood supply. Thus, a graft is dependent on the recipient host bed vasculature. However, grafts have remained a mainstay of reconstructive surgery. In that only a portion of the tissue is transferred, then the movement of grafts has been defined by the nomenclature of split-thickness grafts, full-thickness grafts, and composite grafts. With

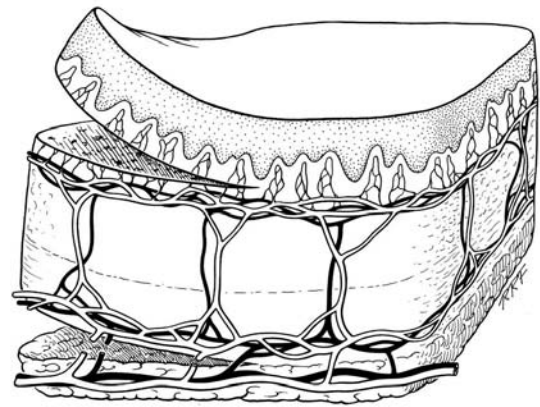
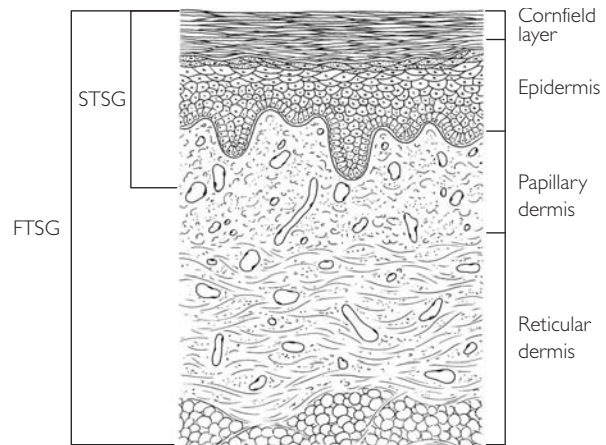


Figure 4.3 Using skin as a model, the levels of a split-thickness skin graft (STSG) and a full-thickness skin graft (FTSG) are illustrated. At the bottom, it is demonstrated that with a split-thickness graft the vessels of the intradermal plexus are exposed, while with a full-thickness skin graft the vessels of the subdermal plexus are exposed.

regards to skin, the term split-thickness graft implies that only a portion of the thickness of the skin has been transferred (Figure 4.3). Because only a portion of the layers of the skin have been transferred then split-thickness grafts have very defined and predictable properties. To understand those properties, one must understand the layers of the skin and their component contribution to the skin's physical properties.

Using skin as a model (Figure 4.4), we realize that skin has two major layers with four subdivisions. The epithelium has a dead layer, which contributes virtually nothing to the properties of the skin, and a living layer which, with the dead layer, functions as a barrier. The dermis has two layers, the layer immediately proximate to the undersurface of the epithelium, which is termed the adventitial dermis, and the deeper layer which is termed the reticular dermis. If one examines the histology of these layers one realizes that the collagen content is much richer in the reticular

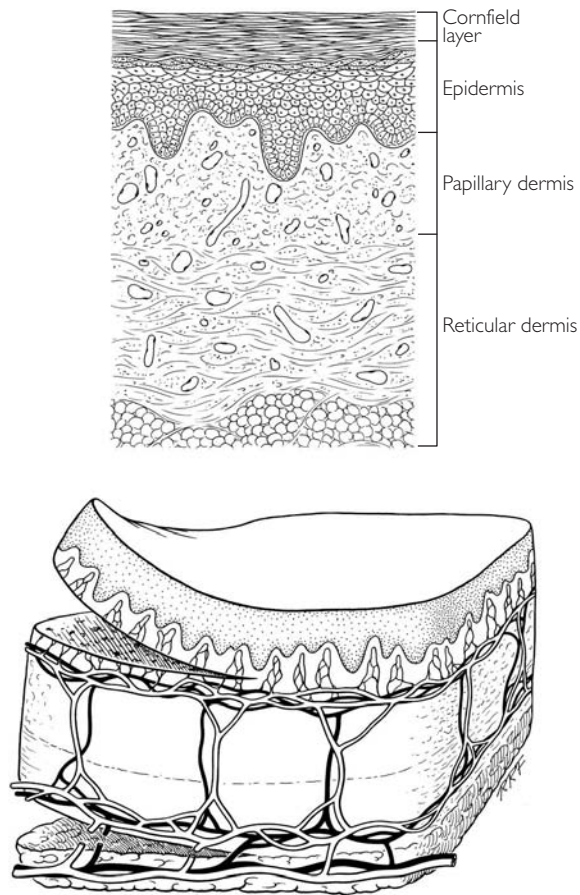


Figure 4.4 The skin has two layers, each with two sublayers. The epidermal layer consists of a cornified or dead layer and the living epidermal layer. The dermis beneath consists of the papillary or the adventitial dermis, and the reticular dermis. Again illustrated at the bottom is the microvasculature of the skin.

layer, and in addition the lymphatics are prominently distributed in that layer. Thus, in the case of a split-thickness skin graft, the majority of the reticular layer is left behind. One then understands that transferred with that unit is the barrier to the outside (the epithelium), the superficial dermis, but the majority of the lymphatics and collagen are left behind (Figure 4.3).

As stated earlier, however, there also remains the issue of vascularity. To this end, one must examine the microvasculature of the skin (Figure 4.4). At approximately the interface of the epithelium and the superficial dermis lies the intradermal plexus. In skin, this is characterized by a very rich distribution of many small vessels. These vessels are then connected, via perforators, to another plexus which exists at the interface of the deep dermis and the subcuticular tissue. This is termed the subdermal plexus, and consists of larger vessels which are more sparsely distributed. In the case of a split-thickness graft, one would predict that many

small vessels would have been exposed. The process of graft take is facilitated, given that the recipient host bed vasculature is equally rich. In general there are more opportunities for these small vessels to connect. To understand this process we must further discuss the process of take.

Take is that process by which the vasculature of the graft becomes truly connected to the vasculature of the recipient host bed. The process is dependent on the bulk of the graft, the number of vessels exposed on the undersurface of the graft, and the number of vessels that are exposed on the recipient host bed. If the recipient host bed has a rich vasculature, and many fine vessels are exposed on the undersurface of the graft, there are many opportunities for those vessels to become connected.

The process of take occurs in two phases. The first phase is that of imbibition. In the literature, this is referred to as plasmatic imbibition, and it refers to that phase in which the graft 'drinks' the nutrients from the adjacent tissue. The graft exists at less than core body temperature and does not have any true circulation. This phase lasts approximately 48 hours. During the next 48 hours, the phase of inosculation occurs in which the vessels of the undersurface, 'the recipient host bed', reach up and 'kiss' the vessels on the undersurface of the graft. As mentioned, in the case of a split-thickness unit, there are many opportunities for this to occur, thus split-thickness units would be predicted to be able to take in less than optimal conditions. The chances are better for that unit. If we summarize, what we can expect from a split-thickness skin graft is a graft which takes readily, and which does not carry many inherent physical characteristics. In most cases, split-thickness skin grafts are somewhat brittle, thin, and non-extensible. In fact, the process of lack of extension is really reflected in the opposite, and in most cases these split-thickness grafts are associated with the tendency to contract.

The full-thickness skin graft (Figure 4.3), on the other hand, is a graft which is cut at the level so that all layers of the skin are included in the graft. The reticular dermis is included and thus the graft carries its own physical characteristics. The subdermal plexus is exposed. This, as mentioned, is composed of larger vessels that are more sparsely distributed; and all things being equal, the opportunities for inosculation may be reduced. The first thing to consider is that full-thickness skin grafts have more mass, the process of imbibition is a bit more tenuous. Second is that they have fewer chances for the recipient host bed vessels to connect, the chances again are somewhat tenuous. The combination of a full-thickness skin graft, in a less

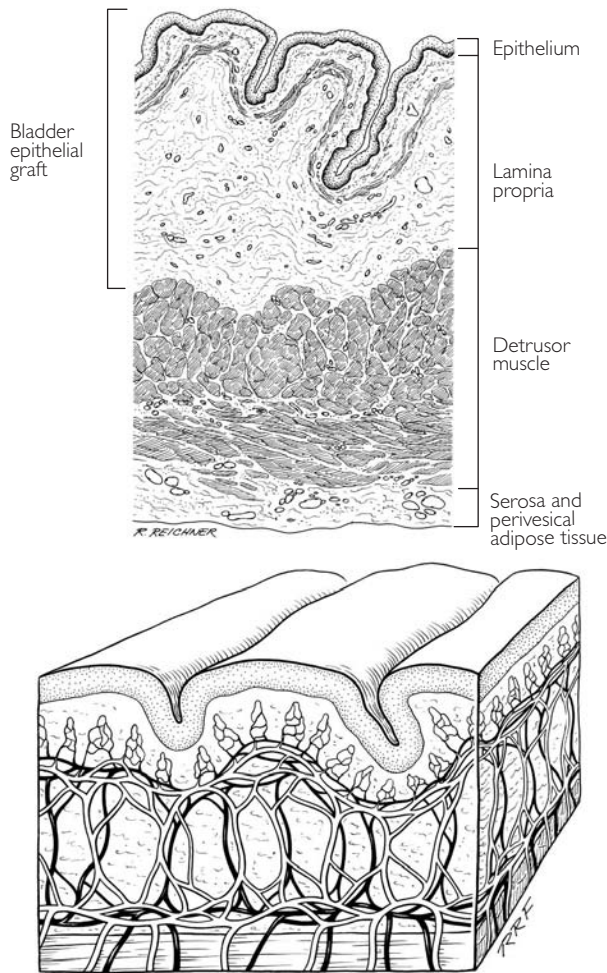


Figure 4.5 Illustrated is a bladder epithelial graft. Notice that the bladder epithelium does have a layered laminar plexus; however, the perforators between the plexuses are much more richly distributed than in skin.

than optimal graft host bed, means usually that the graft does not take. However, a well taken full-thickness skin graft would be predicted to possess its own physical characteristics. The graft would be extensible and somewhat resistant to contraction. The graft, however, would require optimal conditions to take.

Composite grafts 'push the system' even further. In the case of skin, the graft is composed of multiple skin layers. One would then be talking about either a skin adipose (fat) graft or a dermal adipose (fat) graft. In this case, the graft's mass is rather significant, the vascularity of the graft per se may be somewhat tenuous, and without an optimal graft host bed, these grafts will predictably not do well. However, composite grafts have found their way into genitourinary reconstructive surgery in the form of penile enhancement surgery. If one looks at the complications attendant to this surgery, one realizes how tenuous the use of these

grafts can be, even in what are predicted to be optimal conditions. A dermal fat graft for example would expose on its superficial surface the intradermal plexus, and on its deep aspect only the perforators through the adipose tissue. Unless the vessels of the intradermal plexus can carry the complete unit, one may be looking for trouble when using these grafts.

There are many other grafts that have found their way into genitourinary reconstructive surgery other than skin grafts. The bladder epithelial graft has been widely used (Figure 4.5). In the case of the bladder epithelial graft, this is transferred as a full thickness unit. The unit is quite thin and the total mass of the graft is favorable. If one examines the microvasculature, the sublaminal plexus is quite rich. The superficial lamina and deep lamina of a bladder epithelial graft can be compared to the superficial and deep dermis with regards to prediction of characteristics. Thus, a bladder epithelial graft would be predicted to be relatively non-contractile, and to take relatively reliably. However, the bladder epithelial graft has a number of disadvantages associated with it and one is its tendency to desiccate. Bladder epithelial grafts are not useful for reconstruction which requires the graft to be brought to the body surface. Additionally, the bladder epithelial graft has been said to form diverticula. The tendency towards desiccation is indeed inherent to the graft; however, the tendency to form diverticula, in the author's opinion, is probably due to the tendency of surgeons to oversize the graft. The bladder epithelial graft can be relatively difficult to accurately tailor.

The buccal mucosa (Figure 4.6), in many ways, has become the mainstay of urethral reconstructive surgery, at least for now. If one examines the cross-section of the buccal mucosa, one realizes that the buccal mucosa is transferred as a full-thickness unit. The buccal mucosa is relatively thin, and hence the total mass is less. The microvasculature of the lamina beneath the buccal mucosa is that of a panlaminal plexus, as opposed to a layered plexus arrangement. One could thus predict that one would achieve 'split-thickness' vascular characteristics, with full-thickness physical characteristics. Couple that with the fact that buccal mucosa comes from one of the most hostile areas of the body, it is used to being wet, it is used to opposing bacteria and the enthusiasm for the use of the buccal mucosal graft would seem well founded. Not all buccal mucosal grafts are absolutely the same; certainly the cheek graft varies somewhat from the lingual graft, varying further from the lip graft. However, in general, the prediction of behavior of buccal grafts holds for all.

The rectal mucosa graft has been proposed as useful in urethral reconstructive surgery. To the author's

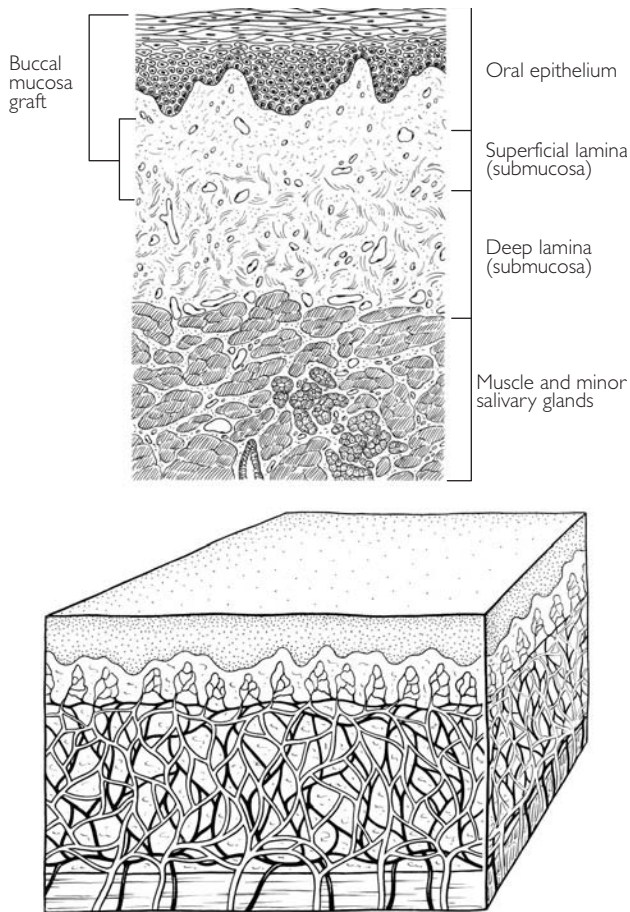


Figure 4.6 Illustrated is the buccal mucosal graft. Notice that the buccal mucosal graft is usually harvested carrying only a portion of the deep lamina. By experience, however, this does convey full-thickness tissue characteristics. Note that the microvasculature is that of a panlamellar plexus.

knowledge, the precise vascular characteristics of the rectal mucosa have not been defined. However, we understand that the rectal mucosa is completely dependent on the vasculature of the muscularis. We would predict that the rectal mucosa graft would behave in the same fashion as skin overlying the somatic musculature. In short then, the graft would be reliant on the connection of perforators to the submucosal plexus. The rectal mucosal graft seems to be a difficult donor site. The author has no experience in the use of this graft. However, it is proposed as an alternative for urethral reconstructive surgery.

The dermal graft has been proposed, for many years, as useful for genital reconstructive surgery. The graft is taken from the deep layers of the skin. The epithelium has been removed, the adipose has been removed, exposing both the superficial (intradermal plexus) and the deep dermal plexus. The dermal graft, from a vascular standpoint,

would be expected to be very reliable with regards to its take characteristics depending on where in the skin the dermal graft is harvested. The dermal graft can be relatively thin or relatively thick, and certainly total graft mass would be an important consideration. By and large, however, the dermal graft can be regarded as a graft that possesses its physical characteristics, does not have a tendency to contract, and which takes relatively reliably.

Vein grafts have been proposed as a better graft for many of the purposes for which dermal grafts have been used. It was proposed that vein grafts did not really take but rather became directly vascularized via the vasa vasorum. Indeed this is not the case, vein grafts seem to take by processes similar to other grafts. When a vein graft is placed under pressure during the take process, the wall tends to thicken, a process that has been called 'arterialization'. In short, vein grafts seem to take reliably with good extensibility. Whether they are better, for the purposes for which they have been used in genitourinary reconstruction than other grafts, has not been proven. They are, however, an excellent graft that is somewhat donor site limited.

The inert collagen matrices have been termed grafts. They are not. The term graft has a very specific meaning that has been previously defined. Likewise, the inert collagen matrices vary and some may be 'more inert than others'. They are ostensibly handled by the body by being incorporated with living tissue. In other words, the material is placed, and then over time the collagen architecture is incorporated. Just how inert these substances are, depends on how well they have been made acellular. Certainly there are cases where acellular matrices can be walled off just as if they are a foreign body; and other cases where they stimulate a rather appreciable inflammatory reaction. Exactly how they work has not been defined. It may well be that they function as a biologic dressing, resisting the forces of wound contraction, and then indeed are invaded by the natural tissues from the edge and from all points of contact. Any off the shelf 'grafts' useful for genitourinary reconstructive surgery are in essence an acellular collagen matrix. Acellular collagen matrices can be cell seeded and for certain uses of reconstructive surgery cell, seeding seems to convey an advantage.

The immediate future seems to lie in the use of cultured tissues. The urothelium has been cultured, as has buccal mucosa. By and large, cultured tissues are either epithelium or mucosa, and they are placed on a carrier substance. That substance has to allow for the cell sheet to be used, operated on, and handled, yet not impede the process of eventual vascularization. A number of centers are vigorously exploring the use of cultured

epithelium and mucosa. To my knowledge there are no long-term follow-up data available with the use of these substances for urethral reconstruction, etc.

The other unit of living tissue transfer is the flap. A flap is tissue that is elevated and transferred. However, the blood supply is either preserved or surgically re-established at the flap's new location. As such, an intimate knowledge of the donor site area where the flap has been taken is essential. By custom, flaps have been classified by either a vascular classification, or a shape of elevation criteria.

In the vascular classification of flaps, the terms random and axial have been used. A random flap is a flap that is transferred on the dermal plexuses (Figure 4.7). The perforators to the underlying axial vasculature, if they are present, have been divided. Random flaps are very useful, but tend to be somewhat less reliable than axial flaps, in that they vary widely depending on location on the body, and also between individuals. An axial flap is a flap in which there is a named and prominent vessel in the base of the flap (Figure 4.8). Axial flaps have been subdivided into direct cuticular flaps, and then the broader category of musculocutaneous and fasciocutaneous flaps. In a direct cuticular axial flap, the vessel lies superficial to the body wall fascia, and is elevated on the undersurface of the flap. In the musculocutaneous or fasciocutaneous system, the vessel is to the deeper structure (i.e. muscle or fascia) and the overlying adipose skin unit is carried via perforators (Figure 4.9). These units are referred to as skin islands or paddles. In areas where there is a musculocutaneous or fasciocutaneous distribution, clearly the muscle and/or the fascia can be carried without a skin island or paddle, the overlying tissues, would then technically survive as random flaps. Axial flaps have a defined cuticular vascular territory which is unique to the donor location, and tends to be very reproducible from individual to individual.

The other classification, that by elevation shape, classifies flaps as a peninsula, island, or microvascular free transfer. As the name implies a peninsula flap has both the cuticular base and the vascular base intact. The island flap has the cuticular base divided, but the vascular base remains intact. The microvascular free transfer flap (free flap) has both the cuticular base and the vascular base divided, the vascularity being restored via microsurgical techniques at the recipient site.

The term island flap tends to be misused. Correctly, the term island flap implies that there is an island of tissue, transferred on dangling vessels. If one, however, transfers an island of tissue on the underlying muscle or fascia, then correctly stated, the muscle is the flap, the fascia is

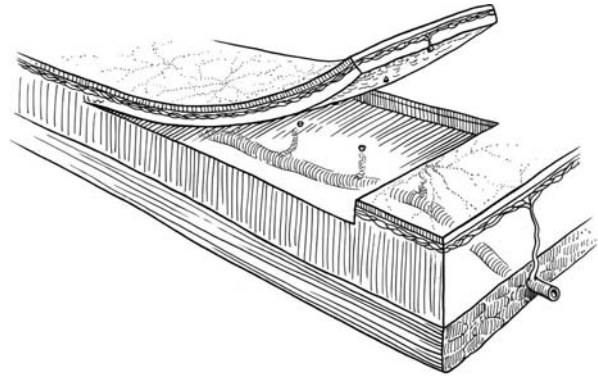


Figure 4.7 Illustration of a random flap. Notice that the flap is carried on the dermis plexuses. The perforators to the deep artery have been divided.

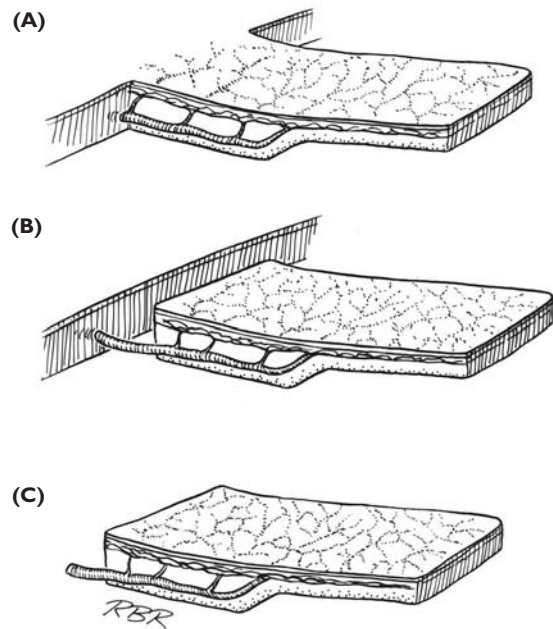


Figure 4.8 Illustration of axial flaps. (A) A direct cuticular peninsula flap, (B) an island flap, and (C) a microvascular free transfer flap.

the flap, and the tissue carried on that flap is then called a skin island or paddle. The difference is a bit more than just semantics. Many musculocutaneous flaps and fasciocutaneous flaps are robust flaps and can be very reliably transferred. True island flaps can be extremely fragile to transfer, the care of the thin vascular pedicle can be difficult during the process of transfer. Musculocutaneous flaps can also be elevated as an 'island'.

All of the local genital flaps are based on the fasciocutaneous system. The fascia is the extended dartos fascia; and, in general, these flaps are used as fascial flaps carrying skin islands.

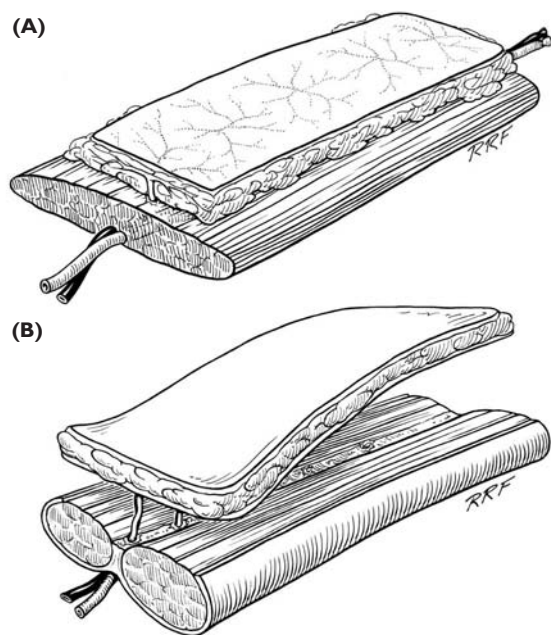


Figure 4.9 (A) Illustration of a musculocutaneous flap, notice that the deep vessels are the vessels to the muscle with the skin island or paddle carried on perforators. (B) Illustration of a fasciocutaneous flap, the deep vasculature is distributed in the fascia, the overlying skin island or paddle is likewise carried on perforators.

FLAPS COMMONLY USED FOR GENITOURINARY RECONSTRUCTION

Groin flap

The groin flap is elevated on the superficial circumflex iliac artery and vein. These vessels are lateral branches of the femoral artery and vein. They lie just caudal to the take off of the superficial inferior epigastric arteries and veins. The cuticular vascular territory runs parallel to the inguinal ligament lateral to the femoral artery. The groin flap can be elevated as a peninsula flap, a true island flap, although the vascular pedicle is quite short, or as a microvascular free transfer flap. The groin flap is useful for issues of the groin itself, and the lower abdomen. The groin flap, elevated as a microvascular free transfer flap, has been used for phallic construction. While the cosmetic results were very acceptable, the groin flap does not create a sensible phallus.

Rectus abdominus flap

The rectus abdominus flap can be elevated as a vertical flap, a horizontal flap, or as a combination of the two. The flap is elevated on the deep inferior epigastric artery and veins which arise from the common femoral artery and

then traverse on the posterior surface of the rectus abdominus muscle. The superior epigastric artery branches from the internal mammary artery passing between the xiphoid and the 8th rib cartilage to become located on the undersurface of the rectus abdominus muscle. Thus, there are two vascular supplies, and each primarily vascularizes is the rostral and caudal aspects of the muscle, respectively. The area at the umbilicus represents an area which can be vascularized from either vessel. The deep inferior epigastric vessels are very easily visualized as they run on the undersurface of the muscle. For use in genitourinary reconstruction, the skin island should be located adjacent to the umbilicus. This is because there are prominent perforators there, making the vascular territory somewhat more reliable in that area, and likewise, the arc of transposition makes those skin islands mechanically easier to use for cases of the genitalia and the difficult groin. The flap is customarily used as a muscle flap carrying a skin island or paddle, although with aggressive dissection can be turned into an island flap (muscle on dangling vessels). Often, for difficult issues in the groin, it is beneficial to use a contralateral flap to the difficult area. When the flap is applied as a horizontal rectus flap, the flap is essentially based on the periumbilical perforators. The muscle is elevated, along with the rectus abdominus fascia. Horizontal rectus abdominus flaps, or combined horizontal and vertical flaps have been used for difficult problems of the genitalia, in women status postvulvectomy, or for difficult issues of the groin.

Gracilis flap

The gracilis flap is elevated on the dominant pedicle to the gracilis muscle. The dominant pedicle comes from the profunda femoris artery and enters the muscle about 9–10 cm below the inguinal ligament. That vessel, however, can be displaced distally and can almost enter the muscle at mid-muscle. This can make the flap very difficult to use. In the classic anatomy, there is usually a small vessel at the midpoint of the muscle which is usually of no consequence and there is a distal vessel which is a branch of the saphenous artery. This artery is the dominant vasculature to the distal aspect of the muscle; however, with classic anatomy, the entire muscle with overlying skin island can be elevated on the proximal vasculature. The muscle is innervated by the femoral nerve; the sensory nerve is the medial cutaneous nerve of the thigh and is usually divided with flap elevation. The gracilis muscle has been used primarily for issues of the perineum. It can be used for vaginal construction, scrotal reconstruction,

and certain issues involving the base of the penis. In some individuals, the flap can be used for difficult issues of the ipsilateral groin. The flap can be used as a microvascular free transfer flap; however, for the purposes of genitourinary reconstruction that has seldom been of benefit. Ortocachea used the gracilis muscle for phallic construction. The phallus that was created was insensible; and to eventually end up with a reasonable phallus, usually required multiple stages.

Tensor fascia lata

The tensor fascia lata (TFL) flap is located on the lateral aspect of the thigh. The mid-axis of the flap is a line drawn from the greater trochanter to the midlateral aspect of the knee. The anterior border can extend to the lateral margin of the rectus femoris and the posterior border extends to the lateral aspect of the biceps femoris muscle. The tensor muscle is supplied by the lateral circumplex femoral vessels. The vessels also supply the rectus femoris and the vastus lateralis muscles. The skin in the distal and lateral one-third of the thigh is predominantly supplied by direct cutaneous perforators from the vastus lateralis muscle. There is a significant cutaneous vessel in the proximal skin of the flap; however, it has been shown that the dominant blood supply to the TFL cutaneous segment is contributed by the vascular network on both sides of the fascia lata. The vastus lateralis muscle is attached to the deep surface of the tensor fascia lata flap throughout its course. The flap is primarily used for difficult skin resurfacing issues of the groin.

Rectus femoris flaps

The rectus femoris muscle originates from the anterior inferior iliac spine and the upper border of the acetabulum and inserts into the patella tendon. It has a purely proximal vasculature. The profunda femoris vessels supply all of the anterior thigh musculature. The rectus femoris musculocutaneous flap is used primarily for groin or suprapubic abdominal coverage issues. For these issues, it is preferred over the TFL flap because of its reliability, ease of elevation, and its proximity. It is not regarded as a totally expendable flap; there can, in some individuals, be some loss of terminal knee extension with elevation of this flap.

Posterior thigh flap

The posterior thigh flap consists of the skin of the posterior thigh that overlies the biceps femoris muscle. It

is based on the branches of the inferior gluteal artery. The flap is a fasciocutaneous flap. This flap is very useful for coverage issues of the groin, and in specific coverage issues of the perineum.

Forearm flap

Forearm flaps can be elevated on either the radial artery or the ulnar artery. When elevated on the radial artery, the skin island is supplied by the septocutaneous perforating branches of the radial artery in the forearm. This flap is sensible, with the medial and lateral antebrachial cutaneous nerves able to be elevated with the flap. The ulnar forearm flap is centered over the ulnar aspect of the forearm. It is based on the septocutaneous perforators of the ulnar artery. These flaps are fasciocutaneous; however, only the superficial fascia needs to be elevated. The deep fascia needs to be elevated only immediately adjacent to the vessel. These flaps have become the mainstay for phallic construction and penile reconstruction.

Pudendal artery flap

The pudendal artery thigh flap is a sensate fasciocutaneous flap that is based on the terminal branches of the superficial perineal artery. The superficial perineal artery is the end artery of the deep internal pudendal artery, the deep branches having been given off, and the superficial branch then dividing into the posterior scrotal artery and the superficial perineal artery. The path of the artery can be easily demonstrated with Doppler. The skin and subcuticular tissue can then be centered over the artery. The dimensions of the flap can be quite versatile in their application. The flap has been used for vaginal construction or reconstruction, and has been useful in difficult cases requiring perineal coverage, and/or male or female urethral reconstruction. The skin island is located proximally on the thigh immediately lateral to the creases of the thigh with the groin and perineum.

Local flaps of the genitalia

By and large, all of the local genital flaps are fasciocutaneous, and are based on either the arborizations of the superficial external pudendal artery, or the posterior scrotal artery. As already mentioned, the posterior scrotal artery is one of the end cutaneous arteries from the deep internal pudendal artery. These flaps have been variably designed. A number of individuals' names have been assigned to the various adaptations of these flaps.

Local flaps in cases of lymphedema

Generally, when the tissues of the genitalia are excised for cases of lymphedema, graft reconstruction is preferable. Most cases causing genital edema are 'systemic' in nature, and thus involve the adjacent tissues of the thigh, the lower abdomen, and often the lymphatic drainage of the retroperitoneum. There are, however, clearly cases where the lymphedematous process is a local one. The skin of the lateral and posterior aspect of the scrotum, thus seems to be spared from the lymphedematous process, and can be used. These flaps, when elevated, are random flaps.

With better definition of flaps and their cuticular vascular territories, and with innovative uses of grafts, genital reconstruction has advanced by a quantum jump in the past several years. We are at a time where we have many options with regards to urethral reconstruction, penile reconstruction, and difficult issues of the perigenital skin.

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5 Endoscopic suturing principles and aids

Michael E. Moran

INTRODUCTION

Suturing is the fundamental method by which surgeons have repaired injury, stopped bleeding, and approximated tissues from the earliest recorded histories. In addition, suturing is often used as a yardstick in measuring surgical skill, laparoscopic dexterity, and mastery of complex, minimally invasive surgeries. Over 63 million surgeries are performed annually in the US and this number will probably continue to rise as the population ages and expands. Suturing is integral to every surgical procedure and it is therefore appropriate that a serious discussion of the methods that minimally invasive surgeons utilize, the rationale for such techniques, the historical contexts, and the evolution of current methods are considered in this chapter. Finally, modern methods that will improve our abilities to augment the dexterity required to perform these complex minimally invasive procedures, including robotic surgery and endoluminal or transluminal surgical suturing, conclude the chapter. Writing about suturing is fraught with the classic 'Catch 22' of how much to include versus what to exclude. Proceeding from the editorial limit on this chapter, a few words must be used to contribute a maximum towards epistemology.

Minimally invasive suturing requires four separate but integrated activities: first, passage of suture (usually via a trocar although there are now suturing systems with suture feeding systems that are becoming available); second is handling the needle and thread (taken for granted activity in open surgery, but highly dextrous and skill specific in the endoscopic realm); third is suturing itself (interrupted, running, and running circular are examples of types); and, finally, knot tying (an truly ancient art form consisting of basic types – bends, hitches, stopper, binding, and loop varieties). All of these aspects of suturing are addressed in turn but it is essential in such a scholarly review to highlight that over 1000 different types of knots have been described alone and the limitations of this manuscript must impose some rational limitation on what can be discussed and what must by choice be left aside. Detailed writings for those interested in more thorough discussions are available from Cushieri and Szabo,¹ Perry,² and Giorgi and Moran.³

Skills for performing minimally invasive suturing are briefly reviewed, and completely intracorporeal methods form the basis for all the discussions in this chapter. For extracorporeal methods, other sources should be sought because at most centers at the cutting edge of technology, the intracorporeal methods described herein suffice. Surgical knot tying is one of the first skills every medical student delights in mastering. One- and two-handed throws are next developed throughout the surgical residency for controlling hemorrhage or reapproximating tissues.

An overview of robotic considerations highlights ongoing sutured techniques and research work. By all accounts and trends, it is becoming increasingly evident that robotic augmented suturing has more than theoretical benefits for the surgeon, as the robotic explosion continues in the US.⁴ The focus in the section on robotic reconstruction highlights concerns regarding the running circular anastomosis versus interrupted techniques. This underlying dilemma explains the renaissance of basic research interest in the vesicourethral anastomosis. This research work is finally beginning to investigate the age old questions, basic to sutured reconstruction with innovative models and reproducible methods (Figure 5.1).

A discussion of the future of minimally invasive sutured reconstructions proceeds by mentioning exciting areas of research that offer promising potential to augment further our surgical reconstructive prowess. A multi-degree-of-freedom needle driver is discussed that might well offer an inexpensive alternative to robotic, computer-enhanced surgical systems (though unlikely ever to rival them again as the technology continues to evolve) that could make widespread complex suturing universally available. Also, an innovative barbed, bi-directional suture that effectively acts like 'suture-glue' is discussed with initial research work that suggests clinical applications that solve all of the theoretical disadvantages of running suture lines. This material is truly innovational and has widespread applicability in every aspect of urologic reconstructive procedures. Finally, the probable next generation of innovative urologic surgical progression, incision less or transluminal or peroral transgastric surgeries is discussed. Already pioneering efforts in this field are making remarkable advances though mechanical devices lag behind those at the

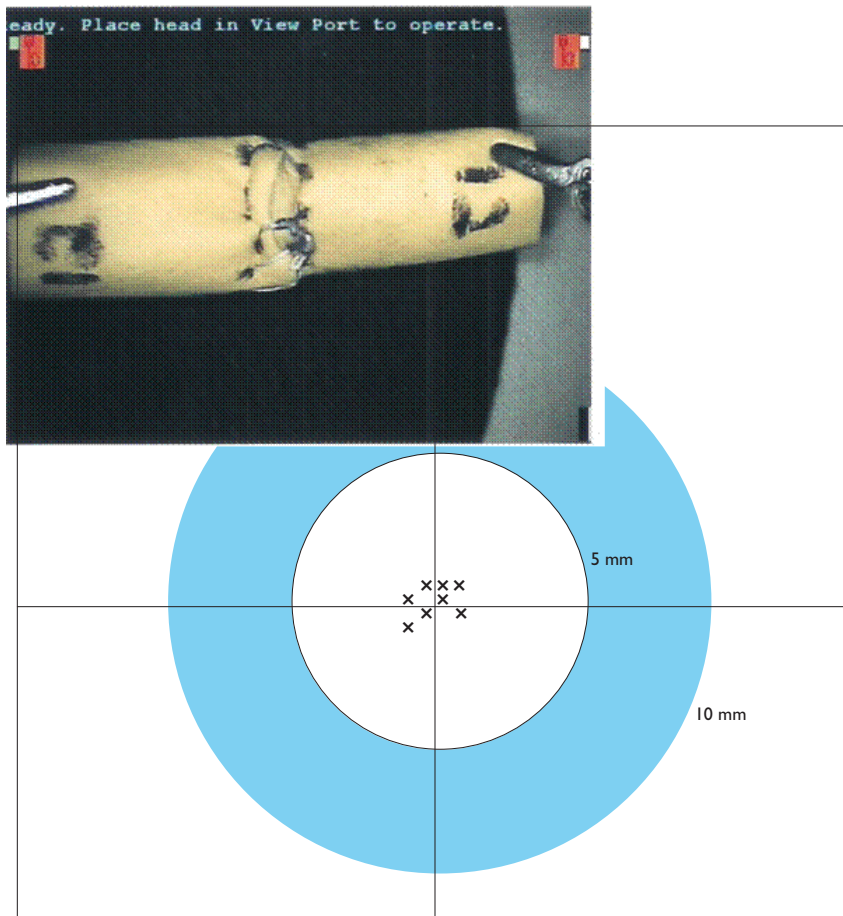


Figure 5.1 Microfiber fiduciary.

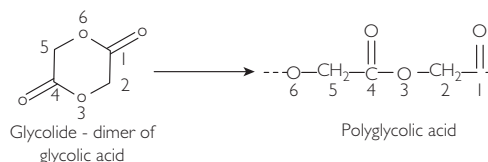
forefront of surgical innovation, which recapitulates our recent laparoscopic era with a degree of *deja vieux*. Yet here again, the robots will be able to morph into the instruments to make all of this 'new age' surgery possible, forcing us to re-evaluate the way we perform surgery, but of course, in a much briefer period of time as the 'law of accelerating returns' applies once more.⁵

BASICS OF SUTURED RECONSTRUCTION

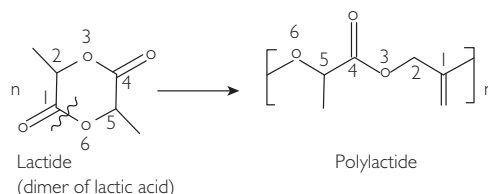
Suture

Suture represents the subject of this chapter, but all too often, it is ignored in such discussions and the attention is turned towards the technique and use of one of the sentinel additions to surgical advancement. Thus, the discussion in this chapter aptly begins with the suture and ends with it as well, with potential new innovations that could in theory revolutionize surgical reconstructions and highlight the potential for technology to alter all of the rules. The ideal suture would be a material that could be utilized in almost any situation, not interact with the physiology of healing, not be labile to bodily

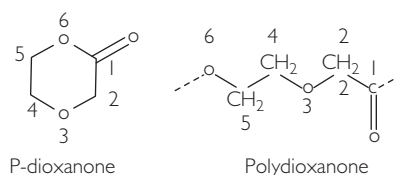
fluids, maintain good tensile strength, be manipulable without weakening, should not fray or break during application, impede bacteriological growth, be non-allergenic and non-carcinogenic, and yet hold a secure knot. A whole host of modern technology has been applied to the manufacture of sutures but there exists no 'ideal' material, hence mandating discussion of many available suture materials (Figure 5.2). Absorbable sutures are many and usually favored by urologic reconstructionists. These include plain or chromic gut, polyglactin 910, polyglycolic acid, and polydioxanone, and each has well recognized physiologic tissue interactions including absorption curves (Figure 5.3). Non-absorbable materials include surgical silk, cotton, linen, stainless steel wire, polyamide polymers (nylon), polyester fiber, and polypropylene. The size of the desired suture depends upon the strength and the tension necessary to perform the work of suturing. Suturing under laparoscopic conditions also produces other influences on the choice of suture materials. Surgical knots must hold and the choice of a woven or monofilament, absorbable versus non-absorbable must be carefully made with this constraint foremost. For urologic applications, intracorporeal suturing with plain or chromic



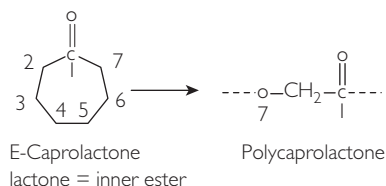
1. Polyglycolic acid (PGA) was developed in the 1970s and is used by Davis and Geck in Dexon™.



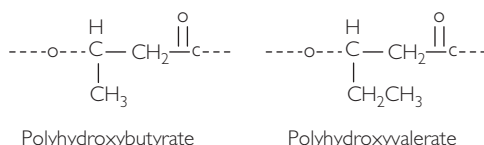
2. Polylactic acid (PLA) usually is used as the L-enantiomer which in crystalline form is absorbed over a long period of time.
3. Copolymers of PGA/PLA are utilized to get the best of both polymers. These are used as the braided sutures Vicryl™ (PGA90/PLA10) (Ethicon, Johnson & Johnson). Injection molding also of these copolymers produces absorbable clips and staples (PGA70/PLA30; Lactomer US Surgical).



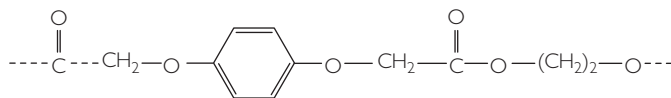
4. This is the first monofilament absorbable suture. It is analogous to polyglycolic acid but is produced by forming a poly-(ether-ester) which lasts longer than the PGA. It is PDS™ (Ethicon, Johnson & Johnson).



5. This semicrystalline polymer is absorbed very slowly, principally by hydrolysis.



6. This is one of those polymers that exists in nature and can be synthesized easily. Copolymers of polyhydroxybutyrate and polyhydroxyvalerate (Bipol) have a wide variety of properties and more rapid degradation than on polymer alone.



7. Poly(ethylene terephthalate), Dacron™ overcomes the loss of mechanical properties from gamma radiation used to sterilize suture materials for medical usage.

Figure 5.2 Polymer suture chemistry.

gut and polydioxanone have advantages for the security of the half hitch throws. Unfortunately the coloring of each of these suture materials is such that if blood is present at the laceration site specified ends, crucial for the orchestrated movements can make for an even more

difficult task. Blood has a tendency to adhere to these suture materials and strict attention to hemostasis is warranted. In addition, the coloration absorbs the light in all these materials except for the blue PDS™.⁶ As multiple untied sutures are placed but not tied as is

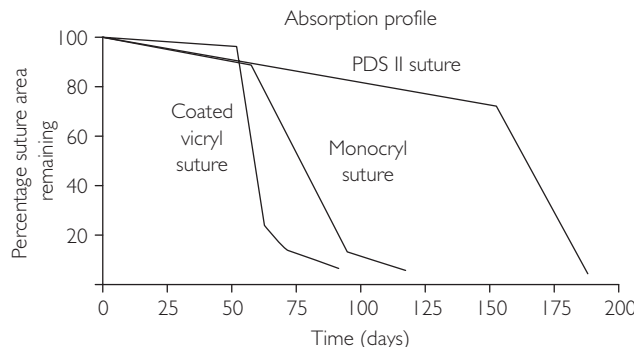


Figure 5.3 Suture physiology.

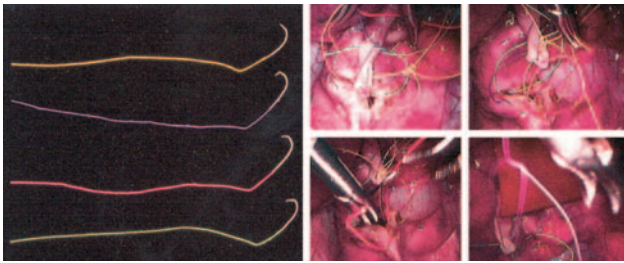


Figure 5.4 Brightly colored fluorescent sutures.

required for complex end-to-end anastomoses, swage and tail ends become indistinct (Figure 5.4, left). Brightly colored, optically fluorescent colors are required to overcome this problem. Currently, dye materials that have been investigated to enhance visibility when exposed to xenon light have also demonstrated carcinogenic properties. Despite this, colors most efficacious for laparoscopic suturing include pink, yellow, green, and purple (Figure 5.4, right).⁷

The next problem for intracorporeal suturing is introducing the correct length of suture material. Available endoscopic suture materials that come pre-packaged, have no relationship to the requirements of the surgeon for the given task. Therefore, the sutures are often long (greater than 80 cm). For a simple stitch the length required should be no more than 8 cm for a surface knot or 10 cm for deep stitches.⁸ Running sutures are more difficult to approximate, but as previously mentioned a rule-of-thumb is to utilize approximately twice the length of the incision.⁹ Keeping the length to the minimum required results in less surgical frustration in manipulating long tail segments, but with running sutures, it can become limiting and increase the dexterity required for knotting with small end pieces.

Needles

Laparoscopic intracorporeal needle configuration has received limited attention by manufacturers to date.

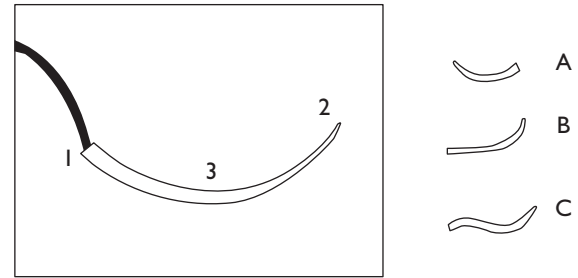


Figure 5.5 Needle shapes useful in laparoscopic suturing.

Because of the limitations of the closed working environment and difficulty of intracorporeal suturing, it might be expected that needle configurations should approximate those of microsurgery. Needles should be high quality stainless steel or carbon steel. Carbon steel needles are harder but are more brittle, and 'on-table' adjustments could result in weakening or breaking of the shaft. Homogenous stainless steel is preferred but more costly. The needle profile of choice has not been rigorously investigated.¹⁰ In our study of intracorporeal bladder neck reconstructions we identified three configurations that facilitated intracorporeal suturing.⁷ A curved 3/8 needle, a ski configuration, and a 'S'-shaped profile were most helpful (Figure 5.5). Needle points can be taper point, cutting, spatulated, or taper cut depending upon the tissue and resistance expected in suturing.

The spatial constraints limit the needle size, shape, and suture lengths needed to most expeditiously accomplish intracorporeal suturing. For urologic pelvic work on the urethra or bladder neck, the deep recesses of the retropubic space permit only a small 1/2 or 3/8 needle (RB-1 or TF) taper point configured needle to allow eversion of knots when reconstruction is performed. Some investigators have advocated straight needles (SC-1 Ethicon, TS-20 Davis & Geck, Endosuture™ WISAP, or ELW US Surgical). These have primary advantage on surface structures or when intracorporeal suturing with straight needle graspers.

Sutures and trocars

Laparoscopic intracorporeal needle driving requires successful, safe introduction of the needle and suture material through a trocar or through the anterior abdominal wall. This requires the knowledge of which needles will pass through a specific sized trocar. The safest method to avoid inadvertent injury to the trocar's flapper valve mechanism and the patient's underlying viscera is to

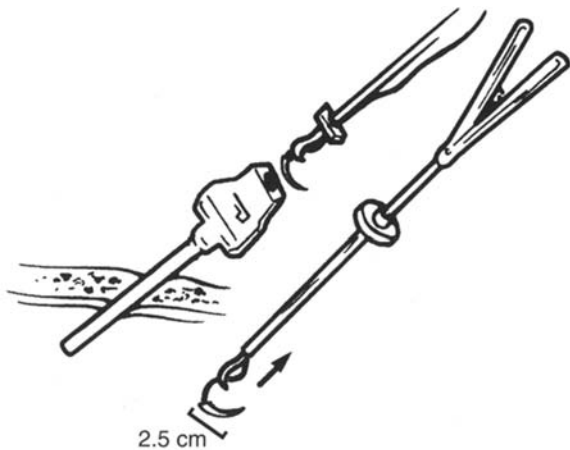


Figure 5.6 Technique to facilitate suture passage through trocars.

grasp the suture 2–3 mm behind the swage, open the valve, and begin passing the needle driver and suture simultaneously (Figure 5.6).¹ The opposite also applies, the needle must be extracted via the trocar past its internal mechanisms. There have been reported instances of needle loss during this phase of suturing. Though a curved needle allows the surgeon a certain mechanical advantage during sewing, it becomes disadvantageous during needle extraction. In order to overcome this, a simple maneuver to straighten the needle essentially eliminates this risk.

Suturing

Laparoscopic urologic reconstruction requires intracorporeal suturing skills, at present, no stapler system exists that allows the diversity of reconstruction that suturing allows. Intracorporeal suturing and knotting represent the most difficult surgical techniques the advanced laparoscopic surgeon can acquire. Reasons for the difficulty in performing intracorporeal suturing are multifactorial. The closed operating environment represents the primary hindrance to mastering these techniques. Fixed portals of entrance limit the ‘approach’ to the targeted suture site. The intra-abdominal viscera are rarely stationary and the ability to move a needle driver’s approach is limited by these fixed entrance portals. Specifically designed assisting instruments can manipulate non-fixed tissues for correct alignment and overcome the problem of fixed portal positioning. In addition, the camera site and the surgeon’s hands also remain fixed. Adding an additional trocar is always possible but it defeats the philosophical goal of minimal access surgery. The camera position of choice when first attempting intracorporeal reconstructions

should lie between the surgeon’s right and left hands. For maximum efficiency the right and left hand portals should not be over an acute angle with each other. The optimal angle to work is 80–110° and each trocar should be more than 8 cm apart at the surface skin sites to allow the maximal ability for the tips to interact. Another important factor to control in this closed, fixed environment is image stability.¹¹ A stable image is readily obtainable by replacing the human camera assistant with a robotic arm. Having outlined the difficulties with intracorporeal suturing, it becomes apparent that the highly dextrous robotic systems can overcome many of these difficulties. Despite this technologic advance, however, surgical knowledge of skills, surgical skills research, and a thorough acquaintance of the movements necessary for flawless suturing still apply.^{12,13}

Knotting

Knot tying represents the final hurdle for proficiency of intracorporeal suturing. Were suturing and needle driving not difficult in themselves, one might say that extracorporeal knotting would certainly be the method of choice. But because the skills necessary for complex endosurgical reconstruction are all linked, knotting represents the last, most difficult task. In addition, once mastered, intracorporeal knots can be manipulated to the endoscopic surgeon’s advantage for complex anastomoses very much like in microsurgery.¹⁴ The key to successfully mastering intracorporeal knotting has been careful, small orchestrated movements of the instruments in both of the surgeon’s hands.

The intracorporeal knot of most utility is the simple square knot. A square knot is two apposed half hitches, one atop the other. To orchestrate the movements necessary to tie such a knot and eliminate wasted motions, each key movement must be identified and the entire sequence practiced. Previously, we discussed the twelve steps in tying an intracorporeal square knot (Figure 5.7).⁷ Step one is the starting position. A ‘C’ shape is made in the suture with the right hand grasping the swaged end of the suture and the left stabilizing the tail. Step two, the right hand only moves to create a loop around the tip of the left instrument. Step three, the right and left hands move together as the left instrument grasps the tail of the suture. Step four, the instruments are pulled in opposite directions paralleling the pull with the suture. Step five, the knot is adjusted to center the first half hitch directly above the laceration by placing more tension on the right or left

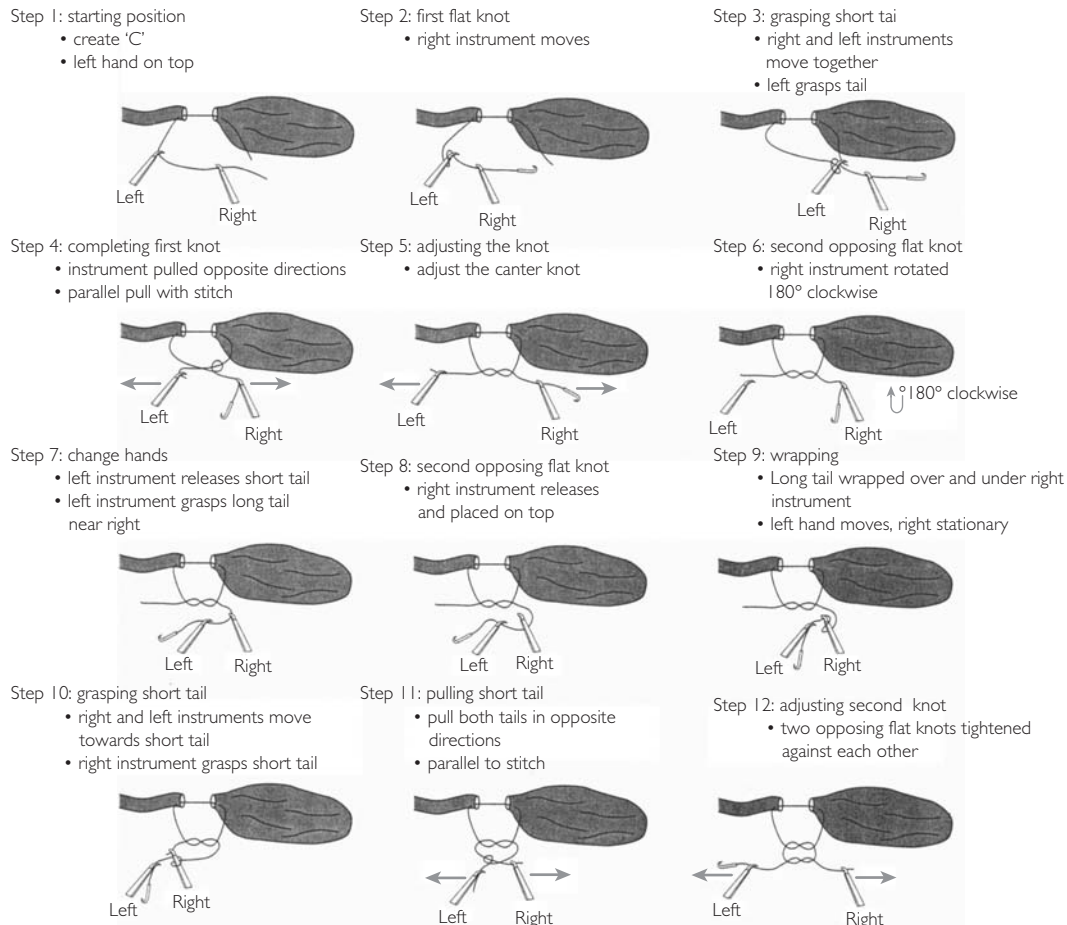


Figure 5.7 Twelve steps in choreographing hand motions during laparoscopic knotting.

hand grasp of suture. Step six, sets up throwing the second half hitch. The right grasps the swaged end and is rotated 180° clockwise. Step seven, the left instrument releases the short tail and grasps the swaged end near the right grasper. Step eight, the right instrument releases the suture and is placed on top, directly in front of the left grasper. Step nine, the left hand moves to create a loop around the right which remains stationary. Step ten, the right and left instruments move together towards the short tail which the right then grasps. Step 11, both instruments are pulled in opposite directions parallel to the stitch. Step twelve, the two opposing half hitches are tightened against each other. This concludes the exercises necessary to orchestrate fluid interaction and minimize wasted motions thus limiting the surgical frustration. Methods other than that described above can be utilized for laparoscopic intracorporeal knotting. These techniques should be prefaced with the reminder that intracorporeal suturing is difficult, but with time, patience, and practice it can be mastered. Utilizing microsurgical principles adapted for the laparoscopic environment, knots and sutures can be manipulated to the surgeon's advantage.

This should be kept in mind when considering intracorporeal suturing techniques and taking short cuts.¹⁵

Recently, the interest in running sutured anastomosis has prompted resurgent interest in this technique, particularly, as it applies to the vesicourethral repair following laparoscopic radical prostatectomy and during the repair phase of robotic pyeloplasty. This running technique, as mentioned in the introduction has created a renaissance of research attention lately and is best addressed in the robotic section below.

ROBOTIC SUTURING

Theory

Master-slave surgical robotic systems are now small enough with mechanized instruments to reproduce the complex ability of the surgeon's arms and hands.¹⁶ The surgical tools are added or subtracted from the devices so that surgical multitasking is possible. To control and co-ordinate the functions of the robot requires a computer.¹⁷ The computer is responsible for

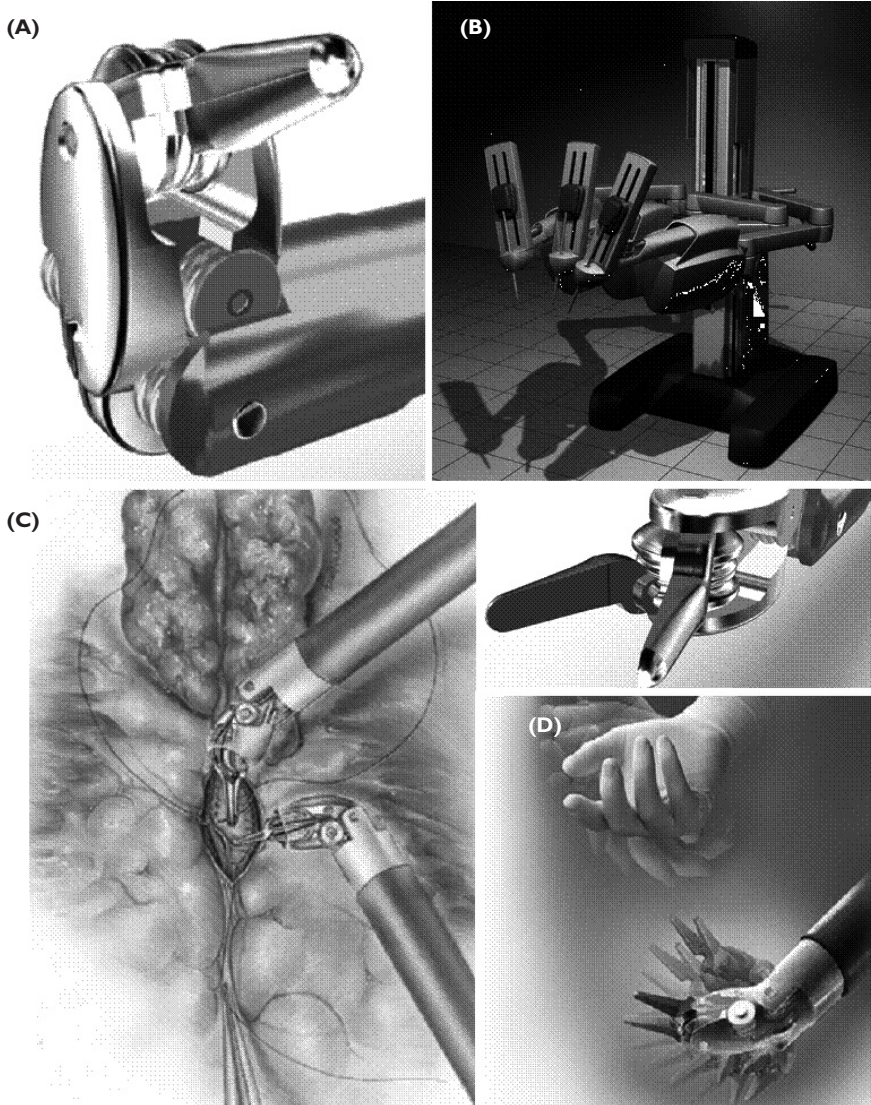


Figure 5.8 The da Vinci™ robotic surgical assist system. (A) The needle driver en fesse. (B) The patient-side surgical system. (C) The system shown diagrammatically during sutured reconstruction. (D) The patented EndoWrist™ system (Intuitive Surgical, Sunnyvale, CA) mimicking a human hand but with increased degrees of freedom.

interpreting the surgeon's actions and transforming them into the movements of the robotic arms and hands. This requires incredible fidelity and incorporates a wide range of motion. The computer is translating the surgeon's movements into precise codes to smoothly and rapidly manipulate the robot (Figure 5.8A). The robot is in direct contact with the patient and the surgeon is removed to the controlling station. As with the laparoscopic surgery removing the surgeon from actually seeing the surgical field, the robotic hands are removing the laparoscopic instruments from actually touching and performing the surgery (Figure 5.8B). The actual robotic tools, or end-effectors, are located at the distal end of long instruments which are inserted into the patient through laparoscopic trocars (Figure 5.8C). The movement of the instruments is controlled manually at the workstation. To allow the end effector to be maximally effective at least six degrees of freedom are necessary (Figure 5.8D).¹⁷

Despite considerable attention just given to suturing techniques, it is felt that one recent suturing method requires separate consideration, that is the running circular anastomosis utilized in many urologic reconstructions. Initially, Hoznek et al described a simplified urethrovesical anastomosis using two semicircle sutures with three intracorporeal knots.¹⁸ Van Velthoven et al further simplified this technique by pre-tying two 6-inch, 3-0 polyglycolic acid sutures (one dyed and one undyed). Both needles are passed through the posterior bladder neck at the 6 o'clock position where the knot rests. Sewing upwards on either side of this results in a watertight closure. If a bladder discrepancy exists, the suture line can be run onto the anterior bladder neck forming a tennis-racket closure. Van Velthoven et al report utilization in 122 laparoscopic and eight robotic assisted radical prostatectomies with an average anastomotic time of 35 minutes. They have had no postoperative anastomotic leaks and at short follow-up have

reported no symptomatic bladder neck contractures.¹⁹ Menon's group has taken this technique and rapidly expanded its clinical application in the robotic assisted Vattikuti Institute Prostatectomy (VIP) series at Henry Ford Hospital. Now with over 2000 consecutive cases presented, the mean total operating time has reduced to 150 minutes.²⁰

This technique is easily transposable to other urinary reconstructive procedures such as Anderson-Hynes dismembered pyeloplasty, ureteroureterostomy, uretero-neocystostomy, and ureteroenterostomy. Preliminary reports utilizing this suturing methodology are beginning to accrue. Much has yet to be learned about this technique. Questions should be numerous. Would a monofilament absorbable suture be better than the braided polyglycolic acid suture? Are two colors necessary? Are the two 6-inch lengths ideal? Is a bolster of autologous tissue important to relieve undue stress upon the anchoring knots? This sutured reconstruction technique appears to facilitate both free-hand and robotic assisted repairs, and may well be a true advance in the technique of laparoscopic reconstructive urology. Basic research may yet solve some of the dilemmas such as the ideal length of a running suture.²¹

Achille's heel of running anastomoses

From the beginning there has always existed a conundrum regarding running sutures on purely theoretical grounds. Advantages of interrupted, single suturing methods include non-reliance upon a single suture, safer, slower allowing for more precision, less ischemia potential, and less scarring. Advances for running sutures include quicker, even distribution of tension around a circle, watertight closure, more hemostatic, and less scarring. Note that some advantages claimed by both are feasible. Disadvantages of single interrupted suturing include slower than running, more knots need to be placed and tied, more knots yield more inflammatory response, greater potential for leakage. Finally, disadvantages for running anastomoses are potential for ischemia is greater, radial force distortion can be caused by two dissimilar areas being approximated, and disruption of entire anastomoses by failure at any point in the single suture. A review of the literature for the past 30 years using PubMed™ failed to substantiate any of these theoretical claims regarding suturing. However, a clear renaissance of interest has occurred in the urologic literature particularly in regards to the vesicourethral anastomoses.²² There are now 101 citations rising exponentially in the

past decade prompted by minimally invasive methods. Sutured anastomoses still predominate; however, there has been a spattering of hybrid methodologies making for more sophisticated repairs. Underscoring the significance of this resurgent research effort are reports by Bariol et al that simply how the suture material is handled affects its integrity.²³ Perhaps seen as no real risk, there are rising numbers of case reports of complete anastomotic separation distant from the time of the robotic surgery, suggesting that in fact, the running techniques do contain an Achille's heel.²²

Running circular anastomoses

The actual problem that may yet come from the technology focusing on this key issue in reconstructive surgery may be the scientific basis whereby all of the questions that have never formally been answered might now be capable of resolution. We recently completed a series of experiments utilizing the da Vinci Surgical System™ and microfiber phantoms to evaluate the number of running suture bites to best perform a simulated vesicourethral anastomosis. Twelve suture bites seemed to be the minimum number that improved measurable variables in this in vitro model (Figure 5.1).²⁴ Is any of this important you might ask? One complete disruption of a urinary anastomosis is a catastrophic complication, and in this era where risk directly correlates with complications, any effort to minimize complications should be sought. Robotic circular running anastomoses are associated with three theoretical disadvantages (the Achille's heel): potential for ischemia, potential for radial force distortion of the anastomosis, and potential for disruption of the entire sutured repair. Suture using 3-0 polyglecoprone 25 may be susceptible to mechanical trauma required for running anastomoses. Learning curve phenomena include non-judicious suture handling, outside during creation of the van Velthoven's stitch, during trocar delivery, or at any point during the anastomosis. Despite the potential for problems, a paucity of reported complications in the literature promotes justifiable enthusiasm in the method, at least until a superior technique evolves.

Solving the potential disadvantages

This brings us to a potential solution to the Achille's heel of running suture lines, that is a hybrid technique such as suturing and glueing. Could a suture-glue be devised that could combine the security of glueing



Figure 5.9 Bi-directional barbed suture material. Quill Medical Inc., Research Triangle Park, NC.

with the unparalleled advantages of absorbable sutures in the urinary tract? Unique opportunities exist for further continued improvement in reconstructive technologies.²⁵ Several intriguing technologies are reviewed for their potential application in the future. Starting with suture technology, it now appears possible that an absorbable suture can be manufactured that does not require knots at all, and may obviate all potential disadvantages of running suturing. Medical textiles research has become increasingly aware of the limitations imposed by minimally invasive surgery. In 1967, McKenzie published a little-known technique of a multiple-barbed nylon suture to repair tendons with greater strength and less inflammatory reaction.²⁶ Ruff from Duke University began work in 1992 on an absorbable barbed suture for cosmetic repairs.²⁷ A barbed suture, in theory removes tension from the apposing suture line decreasing the foreign-body reaction. Further evolution of this suture is reported by Dattilo et al with a barbed bi-directional absorbable monofilament suture.²⁸ In this investigation, the authors used a unique suture of monofilament polydioxanone containing 78 barbs in a spiral pattern around the circumference of the suture. The bi-directional barbed nature of this suture does not require knots for adequate tissue strength (Figure 5.9). The barbed configuration anchors the suture into the tissue and provides adequate apposition while the wound heals with minimal tension and pressure. Preliminary work suggests that the knotless suture material may result in less scar tissue formation, since surgical knots themselves provide persisting areas of inflammation.

We have been investigating just such a material that has no real glue, but has an innovative bi-directional barbed suture that acts like glue yet can be used like standard suture. Using the same fiduciary model that was used to optimize the number of suture bites, we have been investigating Quill™ (Quill Sutures, Research Triangle Park, NC) barbed, bi-directional sutures versus the standard van Velthoven method. The Quill sutures were faster to deploy, were very accurately placed, and most significantly were very fault tolerant. Cutting every fourth suture resulted in no loss of the anastomosis, cutting every other suture resulted in some separation of edges, but again the suture line held against disruption.²⁹

INCISIONLESS ENDOSCOPIC SUTURING

The limits of minimally invasive surgery are being stretched by the ever inquisitive surgical pioneer. There is no reason to believe that the preliminary results of endoluminal and/or transluminal surgeries will stop with the easiest types of procedures and not continue to more sophisticated endeavors.³⁰ Now add a dextrous multi-degree-of-freedom robotic interface and the future should rapidly evolve into a sophisticated surgical reconstructive arena.³¹ Lest the reader think this is the stuff of science fiction, and not scientific reality a brief overview is necessary. Serpentine robots were originally designed off the kinesiology of another complex biologic joint, the spine. The purpose of the serpentine robots is to make a device that has more degrees-of-freedom than does the normal human arm. As computer-control algorithms advance and the means to control the complex maneuvers of greater than 10, 20, or 30 degrees-of-freedom become available, these systems have become increasingly complex. The first such systems were called serpentine because of the ability for robotic arms to 'snake' through passages and pipes to inspect nuclear reactors, fuel tank baffles, and wing spars. To overcome the multiple joint control issues and prevent restrictive backlash, Miyake in 1986 described innovative solutions in control.³² The US Navy funded a spine-like arm for ocean exploration in 1968 which has been called the Scripps Tensor Arm. The final addition in this series is the 1991 Modular Robotic Joint (MJR) robotic arm invented by Mark Rosheim.³³ The advantages of this system are that it allows for more degrees-of-freedom than the human arm, increases modularity, and is fault tolerant, if one joint fails another is capable of providing the needed mobility to accomplish its task. Why would surgeons be at all interested in more degrees-of-freedom you might wonder? Another coming technologic tour-de-force is woundless surgery (Figure 5.10, left).³⁴ This type of complex surgery is also called peroral transgastric endoscopic surgery, and cholecystectomies, appendectomies and tubal bandings have already been performed.³⁵⁻³⁷ Prototype development from companies include a modified gastrointestinal operating scope from Olympus 'R' (Olympus Corp, Tokyo, Japan) and the USGI Medical Transport™ and Cobra™ systems

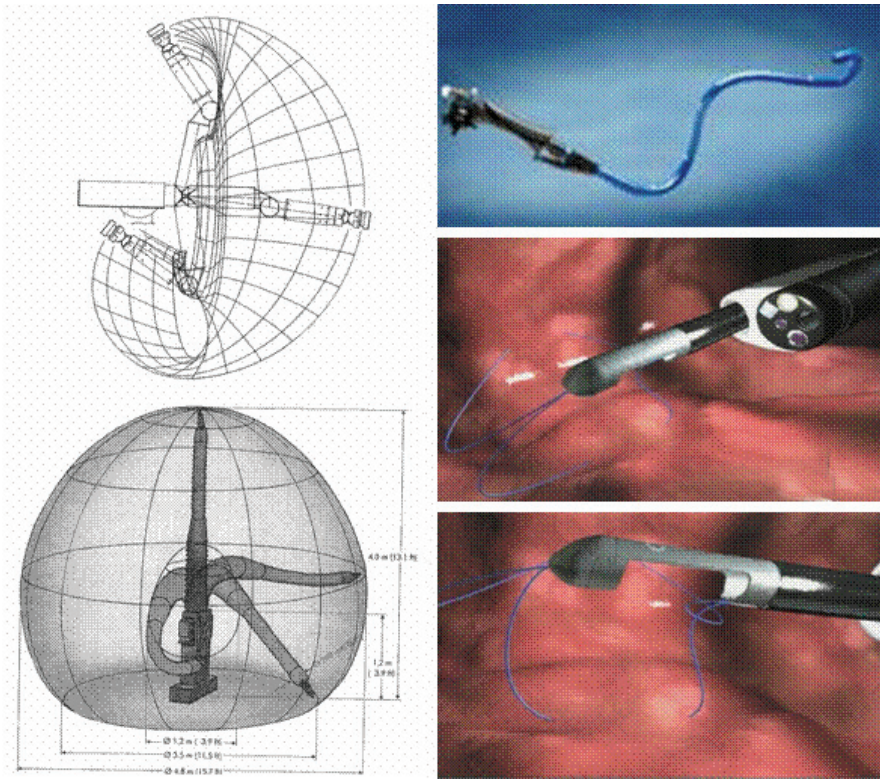


Figure 5.10 Serpentine robot with a view for use during per oral, transgastric intra-abdominal surgery.

(USGI Medical, San Capistrano, CA, USA). The problems with practical application in surgery are the same as those experienced by manufacturers utilizing these maximally dexterous machines, i.e. relating to control. Digital systems will eventually provide solutions so that endoluminal sutured reconstructions will be a viable alternative. In order to achieve more complex tasks, such as nephrectomy or radical prostatectomy, an ultrahigh dexterity robotic arm will be necessary to perform the intracorporeal suturing that will be required (Figure 5.10, right).

CONCLUSIONS

Minimally invasive urologic reconstructive surgery is rapidly expanding at numerous centers around the world. The ability to reconstruct every urologic organ by laparoscopic methods has been reported and replacement via robotic-enhanced methods is well underway. Suturing technology and techniques are the leading methods that are fostering these reconstructions, but the skills and talents of innovators in this field cannot be denied. Mechanical assist technologies certainly offer the capacity to potentiate or facilitate the complex laparoscopic reconstructions necessary for laparoscopic urologic surgery. In one recent report, Antiphon et al describe the use of AESOP™ and

another mechanical arm (Lina arm, Lina Medical, Denmark) to perform complete solo laparoscopic radical prostatectomy.³⁸ Robotic surgery offers the potential to rapidly integrate these skills into a much broader range of urologists, perhaps even bringing these now sophisticated techniques into the hands of all urologists. In one recent investigation on skill, performance between standard instruments and two surgical robotic systems was compared. It was noted that general task performance utilizing standard laparoscopic instruments is faster but with similar precision with either the daVinci or the Zeus™ robots. In performing the more sophisticated reconstructive task of suturing, neither robotic system improved the efficiency (as measured by time to complete the task) as compared with a trained laparoscopic surgeon. However, precision was improved by the addition of the robotic interface. In addition, with knot tying, which involves even more intricate intracavitary manipulations, an improvement in both efficiency and precision with only the daVinci robotic system was noted. The authors conclude that current robotic systems are not cost justifiable currently when compared with skilled, highly trained endoscopic surgeons.³⁹ But one must always filter claims based upon current knowledge and current costs, especially when Luddite tendencies or fear of advanced technologies in replacing fundamental human methods is perceived. It therefore seems obvious that laparoscopic suturing

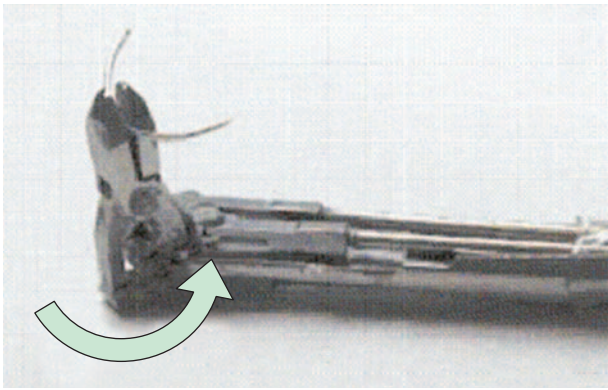


Figure 5.11 Innovative hand-held multi-degree-of-freedom suturing device prototype from Olympus.

skills, no matter how difficult to master, have some merit and there is little doubt that transfer of skills from the laparoscopic realm to the robotic environment is possible. Almost everything in the operating environment at present for the urologic laparoscopist can be considered a barrier to the rapid acquisition of the skills necessary to master suturing. Yet the brightly illuminated, magnified view beckons for microsurgical reconstruction that may be better than our open counterparts can achieve without the routine use of loupes.¹³² Recently the group from Cleveland has used the da Vinci to perform a sural nerve graft during a laparoscopic radical prostatectomy with a mean operative time of 6.5 hours in three patients.⁴⁰ Again, robots should be able to augment our ability here as well, there are now robotic dissection devices that can identify nerves and prevent inadvertent damage to them facilitating complex back surgery.

It would be a major advance in reconstructive surgery if the advantages of the robotic arm–wrist–hand mechanism could be incorporated into a simpler mechanical device. Such a prototype is being investigated by Olympus Medical (Figure 5.11). But it is the control systems themselves that set the current generation of surgical robotic systems apart from a mere multi-degree-of-freedom instrument. As mentioned previously, it is the inherent ability to think, formulate strategy, come up with innovative solutions, and instinctively know what to do and when that separates the surgeon from the machine. Yet, as soon as each caveat is stated, there are fundamental research activities in artificial intelligence that are looking to replicate and even go beyond human capacity. The hallmark feature of the intelligence age, the inception of which we find ourselves at, is that change is going to occur with exponential frequency.⁵ Surgery and medicine should be natural applications of advanced intelligence systems because

the cost of health care is rising so dramatically, the nuances of requiring fault tolerance, indefatigable effectors are in our machines, not us. We cannot achieve the micron degree of accuracy that our robots will, nor the dexterity to accomplish flawless reconstructions with needle and thread. All that is left for this technology to advance to the next level is fusion of multiple technologies, an autonomous ‘high-tech’ suture reconstructive unit that completes a flawless repair, that time is no longer so far away.

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6 Laparoscopic access and exit

Alireza Moinzadeh and Antonio Finelli

Obtaining access to the abdomen or retroperitoneal space is of critical importance given potential associated complications at the outset of the procedure. Repercussions of improper port placement may impede technical feasibility during later steps. In this chapter we outline various available access techniques for laparoscopic peritoneal, extraperitoneal (pelvic), and retroperitoneal procedures. Potential complications of each technique are reviewed. We conclude with a brief overview of steps involved with laparoscopic exit.

ABDOMINAL LAPAROSCOPIC ACCESS

Various techniques exist for access to peritoneal organs each with purported advantages. Transperitoneal urologic surgery may include adrenal, renal, ureteral, and pelvic procedures. Precise location of port placement for specific procedures is covered elsewhere in this book. Here we review the basic principles governing laparoscopic access including Veres needle, open mini-laparotomy (Hasson), optical visualized ports, and direct trocar placement.

For all transperitoneal procedures, prevention of injury to the bladder and stomach is paramount during initial access regardless of technique used. As such, after positioning and prepping the patient, the surgeon must ensure proper bladder and stomach drainage with a Foley catheter and orogastric tube, respectively. The operating camera should be connected and white balanced in the event that urgent visualization of the operative field is necessary.

VERES NEEDLE

Initially developed by Janos Veres for pleural cavity drainage in patients with tuberculosis, Veres needle access is now one of the most commonly used closed access techniques.¹ The Veres needle is a spring actuated retractile needle with blunt tipped trocar (Figure 6.1). The main advantage of the technique is the decreased time required for initial access.

An infraumbilical incision is generally used for initial access for pelvic procedures. Some surgeons prefer

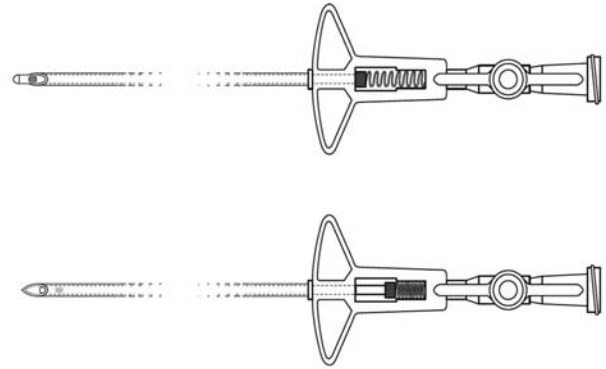


Figure 6.1 Veres needle.

to use an infraumbilical incision as the site of access for upper tract procedures as well. An appropriate skin incision is made to accommodate the planned trocar size. For pelvic surgery, the Veres needle is inserted into the peritoneal cavity at an approximately 45° angle. This angulation has been demonstrated to decrease the likelihood of vascular injury upon entry. The surgeon should be cognizant of patient position; specifically the patient's leveling relative to the floor. For example, the Trendelenburg position often used for prostate surgery may lead to improper angling of the needle jeopardizing vascular structures upon entry. The needle angle should be placed more vertical relative to the skin in obese patients so as to maximize the needle length.

Given the 'blind' nature of Veres needle insertion, several techniques have been developed to minimize the risk of improper position prior to insufflation. Unfortunately, none of these techniques guarantees success. The abdominal wall (skin and subcutaneous tissue) may be grasped and raised manually or with towel clips to increase the distance to the retroperitoneal vessels and bowel. Conceptually, this may serve to decrease the risk of inadvertent bowel or vessel injury. However, whether or not such a maneuver increases the distance of the anterior abdominal wall to the peritoneum increasing the risk of extraperitoneal access remains unclear.

Two distinctive 'pops' are felt during needle insertion corresponding to the fascial and peritoneal layers. Veres access in a more cephalad and non-midline position (where fascial layers are not joined) may yield

three distinctive ‘pops’ corresponding to the external/internal oblique fascia and peritoneum. Prior to insufflation, a Luer lock syringe is used to aspirate the Veres needle. Aspiration of green or brown color liquid may be an indication of bowel entry. In the absence of such aspiration, approximately 1–2 ml of sterile saline is introduced through the needle to dislodge any potential at the tip. A drop of saline placed on the Veres needle top should flow freely if the tip is in the peritoneum. Aspiration of blood may indicate vessel entry. For the neophyte surgeon, the Veres needle should be left in place to serve as a guide to the area of concern and the procedure converted to open surgery. If the patient is stable, a second area of access may be obtained for laparoscopic visualization of the injury and a decision made about open conversion.

After successful access, insufflation tubing is connected to the Veres needle and flow initiated. Low flow (2 l/min) carbon dioxide is preferred to avoid excessive gas insufflation in the event of improper needle position. The pneumoperitoneal pressure readings should be less than 10 mmHg depending on the insufflator used. High pressures of more than 10 mmHg may indicate a preperitoneal Veres tip location. The needle should be removed and reinserted; otherwise, the peritoneum may be dissected away from the anterior abdominal wall. Less frequently, high pressures may indicate a needle tip too advanced within the peritoneum into the retroperitoneal space or bowel mesentery. The surgeon may pull the needle back slightly while observing intraperitoneal pressures. If pressure decreases to less than 10 mmHg, proper placement has occurred.

HASSON OPEN MINI LAPAROTOMY

An approximately 1–1.5 cm skin incision is made at the first trocar location. Access to the peritoneum is then obtained in an open fashion. Sutures are placed in the fascia either medially/laterally or cephalad and caudally. These sutures are then secured to the Hasson trocar (Figure 6.2). The Hasson Trocar is a blunt tipped trocar with two side wings that allow for trocar fixation to facial sutures. This open access technique almost completely eliminates the risk of retroperitoneal vascular injury. The risk of bowel injury, however, is still present. Differentiation of peritoneum and viscera may be particularly challenging through a small incision. Some surgeons prefer this open technique in cases of prior abdominal surgery where the risk of anterior abdominal wall adhesions may be

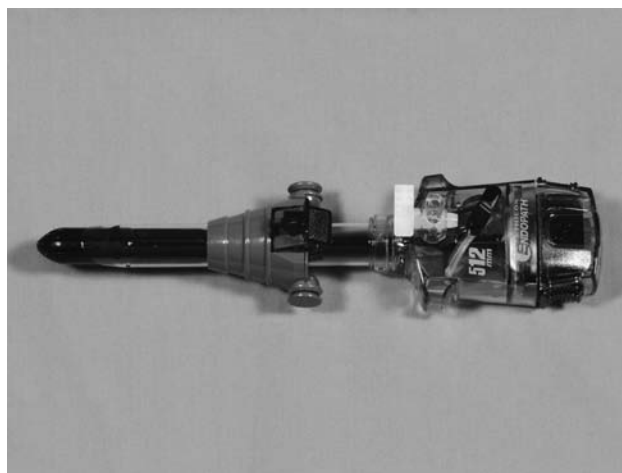


Figure 6.2 Hasson trocar (minilaparotomy insertion trocar).

greater. Disadvantages include longer access time, potential difficulty in obtaining access in the obese patient, and higher risk of carbon dioxide leak rate.

CLOSED TROCAR INSERTION

Popular with gynecologists, this technique relies on direct trocar insertion into the abdomen prior to insufflation.^{2,3} After skin incision, a 5 mm or 10 mm trocar is placed into the abdomen while the anterior abdominal wall is lifted up. The trocar is inserted into the abdomen layers (fat, fascia, muscle) with constant twisting motion. After entry into the peritoneal space, the obturator is removed. The trocar position is then visualized with a laparoscope, and insufflation is initiated.

VISUAL OBTURATOR TROCARS

Visual obturator trocars may be thought of as a combination of Veres or closed trocar insertion and Hasson technique.^{4,5} A zero degree lens is placed within a specially designed obturator/trocar made of lucent material. The lens is focused while within the obturator to allow for optimal visualization. After skin incision, the trocar and lens are inserted jointly in the abdomen (Figure 6.3). Each layer of fascia and peritoneum may be visualized during insertion. Conceptually, this technique offers the unique advantage of closed insertion with simultaneous visualization. However, injuries have been reported during trocar insertion including bowel and vessel injury.^{6,7}

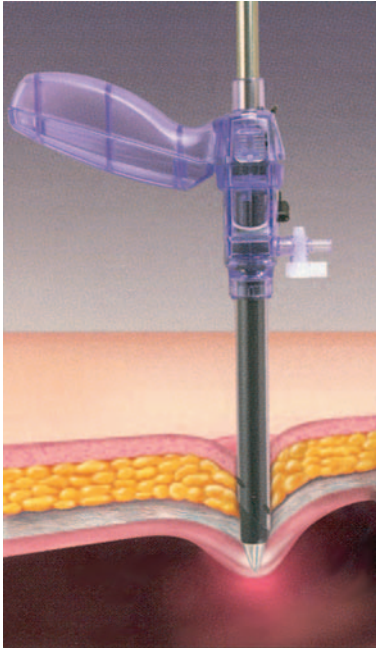


Figure 6.3 Visual obturator trocar placement. Note the laparoscope within the trocar/obturator unit.

SAFEST TECHNIQUE FOR ACCESS

Which of the previously described access techniques is safest, closed (Veres needle, visual obturator trocar, closed trocar insertion) or Hasson? Unfortunately the answer to this question has not been elucidated in the literature. A definitive study aimed at answering this question would require randomization with enough participants in each group to meet the power requirements for detecting a difference between techniques. A meta-analysis by Merlin et al has demonstrated a trend towards a decrease in major complications associated with open access.⁸ However, no definitive conclusion could be based on this meta-analysis or other individual randomized controlled studies.

The safest access approach is the one in which the surgeon has most experience and comfort. The surgeon should be capable of performing several access techniques in the event that one technique fails. In patients with low body mass index of about 20, or patients with multiple abdominal surgeries with a high likelihood of anterior abdominal adhesions, it may be prudent to consider the open Hasson technique.

PLACEMENT OF SECONDARY TROCARS

Initial abdominal pressures are set to 20 mmHg to maximize intra-abdominal pressure for trocar insertion. After trocars are placed, the pressure is decreased to 15 mmHg.

During insertion of subsequent trocars, one should avoid formation of multiple tracts into the peritoneum acting as a chimney effect leading to subcutaneous emphysema. Non-bladed trocars and radially dilating trocars that spread fascia rather than cut fascia have been shown to decrease the risk of subsequent hernia formation.⁹

To decrease postoperative pain it is advisable to infiltrate the proposed site of secondary ports with a fine gauge needle and local anesthetic.¹⁰ This step aids in precise identification of the intraperitoneal location of secondary ports prior to placement. In thin patients, transillumination may assist in identification of superficial vessels and rarely inferior epigastric vessels which may then be avoided.

RETROPERITONEAL ACCESS

Retroperitoneal access is particularly suited for adrenal, renal, and proximal ureteral procedures. The patient should be placed in full flank position. The upper extremities are placed in a padded double arm board. An axillary roll is placed and the lower extremities padded. The patient should be secured to the table with tape without compromise of the lung inflation. Access is obtained at the tip of the 12th rib. An approximately 1.5 cm skin incision is made. The dissection is carried through the external oblique fascia, internal oblique fascia, down to the lumbodorsal fascia. A 1 cm incision is made on the lumbodorsal fascia. The surgeon's index finger is inserted into the retroperitoneum for gentle dissection anterior to the psoas muscle fascia (Figure 6.4A). Although various dissecting techniques have been described (glove insufflation, Foley catheter insufflation), our preference is the commercially available round dissecting balloon (Autosuture, Norwalk, Connecticut, USA) filled to 800 cc (Figure 6.4B).^{11,12} An AutoSuture Hasson balloon port is then placed in the retroperitoneum and the retroperitoneum insufflated to a pressure of 15 mmHg. Additional trocars are placed at the discretion of the surgeon. Care should be taken to avoid inadvertent peritoneal compromise during placement of the anterior most trocar.

Obtaining retroperitoneal access can be quite challenging in the setting of prior open retroperitoneal surgery. Access is possible though at times difficult when multiple prior percutaneous nephrolithotomy procedures have been performed.

PELVIC EXTRAPERITONEAL ACCESS

Extraperitoneal access may be useful for distal ureter surgery, prostatectomy, partial cystectomy, or limited

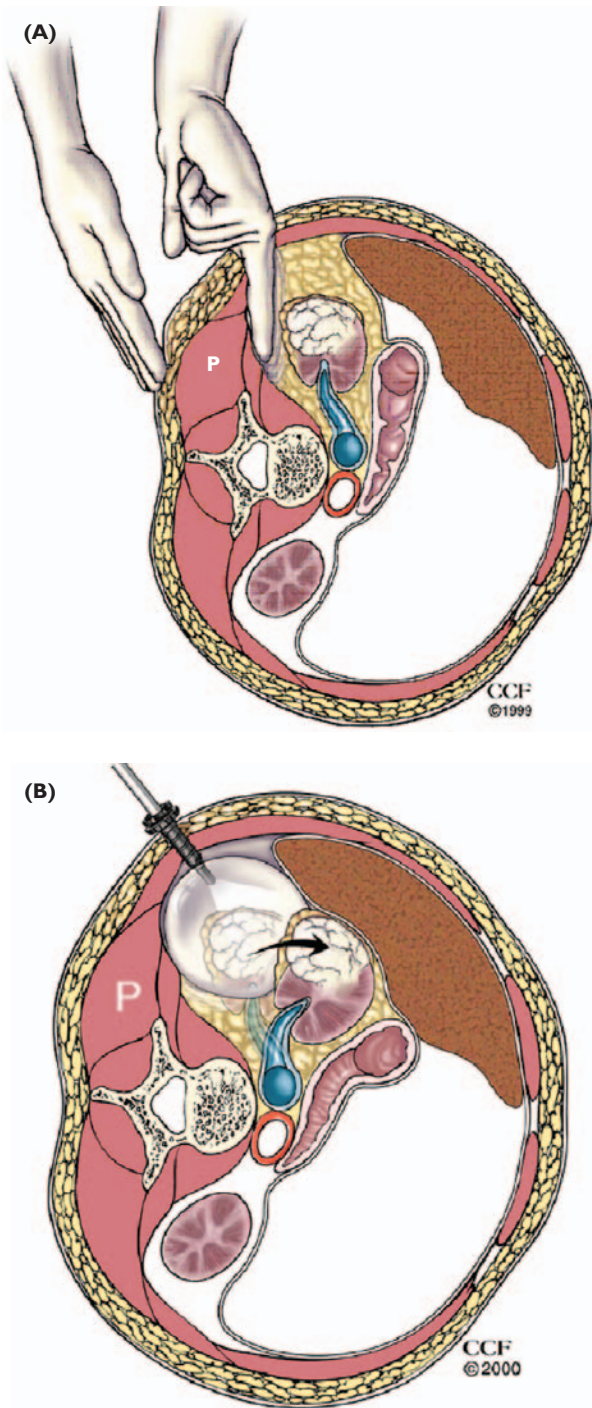


Figure 6.4 (A) Finger dissection of the retroperitoneal space anterior to the psoas muscle (P). (B) Balloon dissection of the retroperitoneum. Note the position of the balloon posterior to the kidney. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

pelvic lymph node dissection. This approach may be particularly suited for patients with multiple prior abdominal surgeries including ventral hernia procedures repaired with mesh.

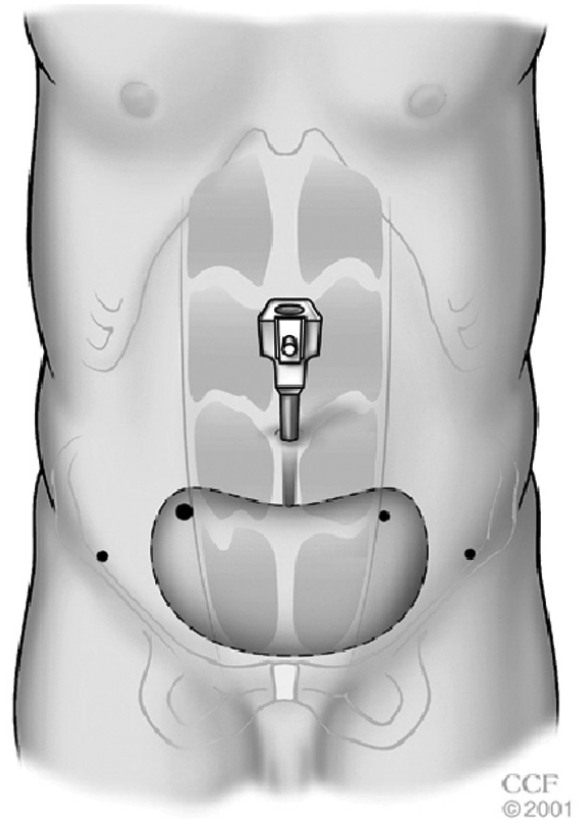


Figure 6.5 Extraperitoneal balloon port dissection for prostate surgery. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

A 1.5 cm infraumbilical incision is made and carried down to the level of the fascia. A stay suture is placed in the fascia caudal to the proposed transverse 1 cm fascia incision made with cautery. While lifting up on the facial stay suture, the surgeon's index finger is inserted between the rectus muscle bellies into the extraperitoneal space. A kidney shaped dissecting balloon is then placed into the extraperitoneal space in the direction of the pubic bone (Figure 6.5). Approximately 600–800 cc of air is instilled into the balloon. Direct visualization of the balloon during insufflation is possible with a 10 mm laparoscope. Visualization guides total insufflation that is necessary for proper dissection. Care must be taken to avoid distraction of the inferior epigastric vessels during insufflation. Additional working space may be obtained superiorly and laterally by gently sweeping the peritoneum from the anterior abdominal wall with the laparoscope while simultaneously applying pressure on the abdominal wall.

LAPAROSCOPIC EXIT

One of the more challenging aspects of laparoscopic surgery is maintaining vigilance at the end of each case.

The surgeon should ensure hemostasis after a period of non-pneumoperitoneum or with the pressures turned down to 10 mmHg. Other basic tenets of exit include release of all carbon dioxide to prevent diaphragm irritation, removal of trocars under vision to ensure port site hemostasis, and closure of 10–12 mm port site fascia with a Cater-Thomason closing device. Inadvertent incorporation of bowel during facial closure must be avoided.

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7 Laparoscopic complications: reconstructive aspects

Kamal Mattar, Alireza Moinzadeh, and Antonio Finelli

INTRODUCTION

The development of laparoscopy represents an important advance in the field of surgery. In the past decade it has evolved to become the standard approach to several operations, replacing laparotomy procedures because of its less invasive nature. As in open surgery, procedure-specific complications are recognized; however, certain features are unique to laparoscopy including an unfamiliar vantage of anatomy, lack of tactile and three-dimensional information, and initially limited operator experience. Urologists considering a laparoscopic approach should be aware of the potential complications and how to manage them safely. This is especially important for urologists in practice who have had little exposure to laparoscopy during their training. Although the rate of inadvertent injuries diminishes with greater experience, complications are unavoidable. Fortunately, the acquisition of advanced laparoscopic skills allows for repair of most injuries through a complete intracorporeal approach, minimizing patient morbidity.

In a large series of 29 966 laparoscopic gynecology cases, the overall complication rate was 4.64 per 1000 cases.¹ The proportions of bowel, vascular, and urologic complications were 34.5%, 32.4%, and 27.4%, respectively. A multi-institutional review of 2407 urologic laparoscopic surgeries showed an overall complication rate of 4.4%; intraoperative vascular injuries were the most common (1.7%), followed by visceral injuries (1.1%).² The risk of complications can be predicted by the complexity of the laparoscopic procedure (ranging from 0.8 to 13.6%); however, a significant decrease in risk was observed with greater surgeon experience, decreasing 4-fold after the first 100 cases.² Improved laparoscopic skills by experienced surgeons also result in a higher rate of pure laparoscopic repair of these complications.¹ With retroperitoneoscopic procedures, the open conversion rates decreased from 10 to 4% as operator experience increased.³ The surgical skills required for complex laparoscopic procedures, including intracorporeal suturing and dissection, are the same skill-set necessary for managing complications.

Concurrently, innovative technological advances have enabled surgeons to expand their minimally invasive reconstruction options. Robotic systems have facilitated intracorporeal suturing and allowed for precise laparoscopic manipulation. Robotic surgery provides a magnified three-dimensional view of the operating field, wrist-like movements of the instrument arms with 6° of freedom, and eliminates hand tremor. Yet the literature is limited with regards to the minimally invasive techniques for reconstructive management of laparoscopic complications. This chapter reviews the more common intraoperative injuries during laparoscopic urologic surgery, and the various laparoscopic techniques to amend these complications.

INTESTINAL INJURY

Visceral injury is potentially a serious complication of laparoscopy, associated with high morbidity and mortality, with an estimated incidence of 0.36%.⁴ Inadvertent injury to the bowel during abdominal or retroperitoneal urologic laparoscopic procedures occurs in 0.8–1.1% of cases.^{2,5} A more recent meta-analysis of laparoscopic renal surgery demonstrates an intraoperative bowel complication rate of less than 0.5%.⁶ The complication rate correlates directly with the complexity of the laparoscopic procedure.^{1,4} Fortunately, most enterotomies are recognized intraoperatively, which reduces the severity of complications and medicolegal actions.¹ This underlines the necessity of evaluating the bowel at the end of the operation for inconspicuous injuries. A history of a prior abdominal surgery or adhesions is associated with a higher rate of enterotomy, complication, conversion, and reoperation.⁷ Furthermore, bowel injury is more common (3-fold higher) when transperitoneal access is used compared with retroperitoneoscopic access.² The small bowel is most frequently injured, typically on the antimesenteric border, due to adhesions on the anterior peritoneum or misadventure during dissection of adhesions. Injuries typically occur from puncture during trocar or Veress needle insertion, laceration

with grasping forceps or scissors, or thermal burns with electrocoagulation. Unfortunately, most thermal injuries are initially overlooked, resulting in delayed perforation from the local inflammatory reaction. Coagulative necrosis of the bowel wall may not arise until days or weeks later. Surgeons must be vigilant to subtle, non-specific changes in the patient's condition in order to make the diagnosis. Computed tomography (CT) of the abdomen with oral contrast may identify bowel perforation by demonstrating contrast in the peritoneal cavity or thickening of a bowel segment.

In surgery, prevention is always better than repair. Patients at risk for significant bowel adhesions should have a thorough bowel preparation prior to surgery. If the odds of an enterotomy are high due to confluent dense adhesions, laparoscopic dissection should be discontinued. Similarly, releasing a segment of bowel without complete inspection for the presence of a small defect may lead to postoperative complications that are more difficult to rectify than a primary repair. Although complete examination of the bowel during laparoscopy is challenging, a large proportion of bowel can be examined by careful utilization of atraumatic graspers. If an enterotomy is identified, careful evaluation of the remaining bowel is encouraged since lacerations may involve both sides of the bowel, multiple loops of bowel, or vascular structures in the mesentery.

The management of laparoscopically induced bowel injury can be divided into laparoscopic or laparotomy repair, and rarely, conservative management. Conservative management with percutaneous drainage to reduce the risk of abscess formation, along with antibiotics and expectant treatment, is reserved for patients in sepsis or cardiovascular collapse. Laparotomy, which implies conversion to open surgery, may be necessary for complicated cases. Most laparoscopically induced bowel injuries are recognized during surgery, and immediate repair is indicated. Often all that is necessary is oversewing of serosal injuries due to small perforations or burn sites to protect from fistulization and abscess formation. Burying the injured serosa with a simple figure-of-eight silk or vicryl suture applied in a horizontal rather than vertical plane to minimize luminal narrowing is best. Alternatively, one may place a purse-string suture just beyond the demarcation of the injury.

It is prudent to excise deep burn sites that are at risk of necrosis, and repair of deeper perforations should incorporate the seromuscular layer. A suture passing through the underlying mucosa is inconsequential as long as it does not incorporate the opposite wall. More extensive enterotomies may require segmental bowel resection with primary reanastomoses, placement of

an abdominal drain, and lavage of the peritoneal cavity with copious amounts of saline solution. Although this can be carried out laparoscopically by urologic surgeons with expertise, surgical consultation to repair the injury and consider temporary colon diversion is more prudent. In cases where the bowel is not prepared and there is gross fecal spillage, a diverting stoma may be necessary. Intraoperative surgical consultation is recommended for all duodenal injuries because duodenal leaks are associated with high morbidity and potential for serious complications. Duodenal injuries are usually managed by open conversion, repair or resection of the injured segment, and a duodenojejunal anastomosis. Delayed diagnosis of bowel perforation is mostly treated with a laparotomy in order to evaluate the entire abdomen.⁴

The rate of rectal injury specific to laparoscopic radical prostatectomy is 1.3%.⁸ The majority of injuries occur during dissection of the posterior surface of the prostatic apex. Rectal injuries during difficult laparoscopic radical prostatectomies can be minimized by intrarectal digital manipulation while incising Denonvilliers' fascia and dissecting the posterior surface of the prostate. Insufflation of air into the rectum may help to identify smaller injuries that could be easily missed. Patients with failed primary repair or delayed diagnosis risk greater morbidity, including peritonitis, abscess, rectourethral fistula, colostomy, and prolonged urethral catheterization.⁸ Inadvertent lacerations of the rectum should be repaired with a two-layer laparoscopic closure, incorporating the inner mucosa and outer seromuscular layers.^{5,8} Following radical prostatectomy, it is important to achieve a watertight vesicourethral anastomosis, and consideration should be given to interposition of an omental tissue flap between the rectal repair and vesicourethral anastomosis. An additional drain should be placed posterior to the bladder in proximity to the rectal repair. Anal dilatation is not required, and a colostomy is rarely necessary. Guillonnet al recommend insufflation of the rectum with air to confirm integrity of the repair.⁸

Postoperatively, broad spectrum antibiotics should be given prophylactically if the bowel lumen has been entered. For most superficial or partial-thickness injuries where the lumen has not been entered, antibiotics are not necessary. If the bowel perforation is small (<1 cm in diameter), there are no postoperative dietary restrictions, but the patient should be informed of the potential delayed complications. For larger defects, oral liquids are delayed until the next morning, and if the patient is doing well, a low-residue diet may be initiated.

VASCULAR INJURY

Despite being the most devastating complication, the true incidence of vascular injuries during laparoscopic surgery is unknown. Many of the non-lethal vascular injuries go unreported, and those caused by non-trocar injury are almost never reported.⁹ Vascular injuries are the most common cause of death related to trocar insertion; 74% of the fatalities were associated with profuse bleeding.¹⁰ Access related complications in laparoscopic renal surgery series are rare, with reported rates of less than 0.5%.⁶ Meta-analysis also showed that the most common major complications were venous and arterial bleeding (1.8% and 1.0%, respectively) that tended to occur during dissection around inadequately exposed large vessels, as in laparoscopic nephrectomy or retroperitoneal lymph node dissection.⁶ By contrast, in laparoscopic prostatectomy, where large vessels are rarely encountered, bleeding significant enough to warrant open conversion is rarely encountered.¹¹ Inadvertent injuries of renal vessels are best avoided by a clear demonstration of the vascular anatomy and potential anomalies. CT or magnetic resonance imaging (MRI) is standard practice prior to renal surgery, and the addition of three-dimensional vascular reconstructions for seemingly complex cases provides a clear outline of the arterial and venous anatomy to minimize the risk of injuries.

Secondary port placement of the lateral trocars, which should always be observed directly, is the most common cause of inferior epigastric vessel laceration.⁹ Complications have been associated with all types of trocars, and improved safety has not been demonstrated for devices specifically designed to decrease the risk of injury.¹² Injuries to major abdominal-wall vessels can usually be avoided by selecting locations for port insertion away from the midregion of the rectus muscle. In thinner patients, the silhouette of abdominal-wall vessels may be seen by transillumination with the laparoscope. If an epigastric vessel is lacerated, the trocars should be left in place for the duration of the case, since rarely will these injuries result in hypovolemic shock. Continued bleeding from the abdominal wall can be troublesome if it continues to drip into the operative field obscuring vision. At the end of the procedure, ports should be removed and sites inspected under direct vision with minimal insufflation pressure. Persistent bleeding can be directly controlled intracorporeally with a figure-of-eight suture through the fascia, muscle, and peritoneum to occlude the area of bleeding. Electrosurgical desiccation is rarely effective. If bleeding is extensive, sometimes

apparent in the form of an expanding hematoma, the two ends of the bleeding vessels must be sutured cephalad and caudad with through-and-through abdominal loop sutures. The loop sutures are placed via the use of a port closure device, such as the Carter-Thomason, and are left in place for 8 hours prior to removal.

Laceration of mesenteric vessels most commonly occurs with trocar insertion in patients with previous abdominal surgery. Fortunately most of these vessels are small and rarely lead to life-threatening bleeding. Although suture ligation is an option, most small-to-medium size vessels can be coapted with bipolar electrosurgical devices. Care should be taken not to devascularize the blood supply of the bowel segment; hence, short bursts of electrosurgery are preferred to minimize thermal damage.

Larger vessel injuries during laparoscopic surgery are the most catastrophic, usually occurring during abdominal access. Injuries to the aorta, vena cava, and iliacs occur in 0.25% of laparoscopic cases during introduction of the Veress needle or the initial trocar.¹³ These injuries are heralded by prompt and vigorous return of arterial or venous blood. Immediate open conversion is mandated in these circumstances, due to the lack of ports to manage the situation laparoscopically and insufficient exposure to control the hemorrhage. Major vascular bleeding may also result from inadvertent puncture by an operating probe, laceration during adjacent dissection, avulsion, clip dislodgment, or stapler malfunction. Venous structures are more easily damaged than arterial ones because of their thinner walls. Control of a major bleed demands rapid recognition and, depending on the case, conversion to an open approach to achieve manual tamponade. The best immediate solution is direct compression of the bleeding site using a blunt laparoscopic grasper with a sponge while the abdomen is being opened. Laparotomy can be performed rapidly by cutting down on the laparoscopic lens. An adequate supply of blood must be made immediately available for transfusion. After control of the hemorrhage, dissection is carried out to achieve sufficient exposure for placement of vascular clamps proximal and distal to the injury. If significant reconstruction is needed, it is best carried out by a vascular surgeon.

The introduction of vascular clamps to laparoscopy, in addition to advanced suturing techniques, has significantly improved our ability to control bleeding intracorporeally. Laparoscopic reconstruction of the aorta is now a feasible and reproducible procedure; however, it is labor intensive and many surgeons feel that it is unwarranted.^{14,15} Nonetheless, major vascular injuries

have been repaired intracorporeally by skilled laparoscopic urologists.^{16,17} Although, immediate open conversion may be the safest option, laparoscopic hemostatic pressure can be effectively applied either by introducing laparotomy sponges through a large (12 mm) port or by applying pressure using the suction cannula.¹⁸ Since the pneumoperitoneum may tamponade venous hemorrhage, insufflation pressure should be increased to 20 mmHg and the patient placed in Trendelenburg to minimize the risk of carbon dioxide embolism. Carbon dioxide embolism, an often fatal complication, can occur during laparoscopic repair of a venous laceration, but only after significant blood loss or intravascular volume depletion.¹⁹ Venous carbon dioxide emboli are unlikely to occur during the initial episode of brisk bleeding, affording time for an expeditious repair. This risk can be further minimized by increasing the central venous pressure with bolus infusions of intravenous fluids.

Pelvic surgery demands advanced laparoscopic skills, and, thus, laparoscopists possess the technical ability to repair inadvertent vascular injuries without converting to open. The offset anatomic position and variations in course and anatomy of the iliac vessels predisposes them to injury during lymph node dissection. Profuse bleeding from the internal iliac artery can be safely controlled by ligating the artery proximal to the site of injury. If the external iliac artery is lacerated, hemostasis must be initially secured with vascular clamps. Laparoscopic repair can then be accomplished by suturing the defect with a two-needle single-knot technique. Due to well established collateral blood supply, more distal iliac branches can be safely ligated if there is a loss of hemostasis.

After initial tamponade of the bleeding, it is important to re-establish orientation of pertinent anatomy, particularly when the field of view has been obscured. Introduction of additional ports may facilitate tissue dissection and exposure of the bleeding vessel. Proximal control may be transiently achieved with bulldog clamps; however, laparoscopic Satinsky clamps are more reliable since they have higher occlusive strength.²⁰ If vascular clamp placement is inadequate due to poor exposure, the edges of a lacerated vein can be held together with laparoscopic graspers for closure. Another effective technique to stop profuse hemorrhage is by rapidly grasping near the site of bleeding with an 'Allis clamp', then twisting 90° to tamponade with the adjacent tissues. Once the extent of injury is defined, judicious placement of titanium clips or application of an endoscopic stapler may be satisfactory. For more extensive injuries, laparoscopic

vascular clamping and placement of a running suture along the length of the injured vessel may be necessary. A rapid approach to closing longer venous lacerations is to run a 6-inch segment of 5-0 monofilament suture on an RB-1 needle with a preapplied clip on the distal end and another applied to the opposite end upon completion, eliminating the need for intracorporeal knot tying.^{16,21} Avulsed vessels may also be controlled by a figure-of-eight suture. Upon completion, the intra-abdominal pressure should be lowered to verify the adequacy of the repair. Failure to control hemorrhage by these measures, the presence of hemodynamic instability, or insufficient laparoscopic expertise should prompt immediate open conversion.

NERVE INJURY

The path of the obturator nerve should be clearly defined pre-emptively during pelvic lymphadenectomy to avoid inadvertent injury. If the nerve is transected sharply, its sheath can be reapproximated with fine polypropylene sutures in an interrupted fashion to achieve a tension-free anastomosis.²² Spaliviero et al described laparoscopic end-to-end coaptation with four, 6-0 nylon, epineural stitches, and demonstrated functional recovery.²³ In general, mobilization of the obturator nerve to gain additional length is not feasible since it is fixed at both ends. In such cases, interposition of a nerve graft concurrent with an intraoperative plastic surgery consultation are necessary.

URINARY TRACT INJURY

The risk of urologic complications during gynecologic laparoscopy is 13.2%; however, like vascular injuries, intraoperative urinary tract injuries are poorly reported, especially by urologists.¹ The incidence of ureteral injury alone is estimated to be 1–2.2%, and it is a markedly higher rate when related to gynecologic surgery.^{9,24} Skilled laparoscopists performing radical prostatectomy report the risk of ureteral injury to be 0.3%, predisposed by dissection of a prominent median lobe in a large prostate.²² Ureteral injuries are also predisposed during extended laparoscopic pelvic lymphadenectomy and with the transperitoneal approach wherein the vas deferens and seminal vesicles are dissected in the retrovesical cul de sac. Overall, ureteral injuries are also under-reported since many are silent; in addition, only 30–50% of reported ureteral injuries are recognized intraoperatively.⁹

The most common urinary injury is to the bladder dome, secondary to suprapubic trocar placement. Many of these injuries are unrecognized intraoperatively and may result in unforeseeable complications.⁹ If the patient has a Foley catheter in place, the insufflating gas will leak into and fill the urinary reservoir bag with air. Bloody urine is another clue to a possible bladder perforation; however, this is also a normal consequence following extensive surgical handling of the bladder or ureter. Retrograde filling of the bladder with methylene blue or injection of dye intravenously aids the identification of an inconspicuous perforation of the bladder or upper urinary tracts, respectively. Most bladder injuries are small, and they can be treated conservatively by catheter drainage for 7–10 days. Larger lacerations are repaired by laparoscopic closure of the defect in one or two layers using an absorbable suture, followed by catheter drainage for 7–10 days. Care should be taken to avoid damage to the ureteric orifices or trigone during the closure.

Ureteric injury is a dreaded fear of laparoscopic surgeons since it carries a real risk of associated kidney loss. The common use of thermal hemostasis devices, as well as stapling devices, has accounted for an increase in ureteral injuries.⁹ There is usually a delay to the diagnosis of most ureteral injuries, but those that completely obstruct the ureter present promptly. Delayed injuries lead to extravasation of urine or result in ureteral stricture with potential renal damage if not recognized. The safest method to avoid inadvertent injury is to empirically dissect out and identify the ureter during complex cases. Care must be taken to avoid interrupting the ureteral adventitia and vascular supply preventing avascular necrosis. Alternatively, when peristalsis of the ureter is visualized, it can be mobilized medially with the attached peritoneum away from the pelvic side wall and out of harm's way. Lighted stents have been used in difficult cases to aid in identification of the ureters.

Rapid recognition of ureteral injury and urologic repair to protect the associated kidney is essential. Limited areas of thermal injury may just require stenting to prevent stenosis and urinary extravasation, until healing is completed. For small lacerations, stenting and suturing the defect with a fine absorbable suture is appropriate. If the proximal or mid-ureter has been transected, a tension-free anastomosis over a stent can be done laparoscopically by expert surgeons. The distal ureter is amenable to a laparoscopic extravesical uretero-neocystostomy performed over a ureteral stent. Any desiccated areas at risk of necrosis should be excised first. Long ureteral defects have been successfully reconstructed with reconfigured colonic or ileal segments laparoscopically in both humans and animal

models.^{20,25} Segments from the intestinal tract were isolated and transversely reconfigured into long pedicled tubular grafts, which were then interposed into the ureteral defects. Even repair of traumatic ureteropelvic junction disruption has been feasible with robot-assisted laparoscopy.²⁶ After any repair of the urinary system, a drain is routinely left in place.

SOLID ORGAN INJURY

Abrasions, lacerations, or capsular tears of solid abdominal organs by laparoscopic instruments occur accidentally or during mobilization or retraction of these organs. Laparoscopic renal/adrenal surgery was associated with a 9% rate of liver puncture with the initial insertion of a Veress needle for primary access; however, none required intervention.²⁷ Other reviews of laparoscopic renal surgery suggest solid organ injury rates between 0.5 and 2.5%.^{6,21,28}

Minor bleeding from inadvertent solid organ injury can usually be controlled with either monopolar or bipolar electrocoagulation. More recently, the harmonic scalpel, ultrasonic shears, and neodymium:YAG laser have been added to the armamentarium of laparoscopists. Superficial capsular tears or persistent hemorrhage have been efficaciously managed by the wide coagulative spray of the argon beam.²⁰ Minor residual bleeding can be controlled by direct compression, placement of a sheet of surgical cellulose, followed by topical injection of a sealant over the bleeding sites. Sealants such as fibrin glue or bioadhesive FloSeal™ (Baxter International Inc., Deerfield, IL) have an important adjunctive role in achieving final hemostasis of cut parenchymal beds, and they are conveniently packaged for laparoscopic delivery.^{29–31} Although the above hemostatic modalities can achieve surface coagulation of minor oozing, they are inadequate for controlling pulsatile arterial hemorrhage from considerable parenchymal vessels. Bleeding vessels are better controlled by placing a suture ligature deep into the tissue to minimize the risk of tearing out of friable parenchyma. Unfortunately, recalcitrant hemorrhage may necessitate resection of the bleeding segment, removal of the organ and/or emergent conversion to open surgery.

Injuries to the gallbladder are most easily managed by laparoscopic cholecystectomy where a general surgery consultation is mandatory. Similarly, bleeding from the adrenal or spleen can be efficaciously managed by adrenalectomy or splenectomy, respectively. A suction drain is only necessary in cases of pancreatic injury, to minimize the risk of serious complications

secondary to leakage. Extensive pancreatic injuries, typically to the tail of the pancreas during left-sided adrenal or renal surgery, necessitate a distal pancreatectomy. This can be carried out laparoscopically with a stapling device; however, if an open duct is identified, it must be closed with a figure-of-eight suture. Intraoperative consultation from a general surgeon should be sought for any doubtful cases.

DIAPHRAGMATIC AND PLEURAL INJURIES

The risk of intraoperative diaphragmatic or pleural injury during laparoscopic renal surgery is less than 0.5%.⁶ These injuries can occur while releasing the splenic attachments on the left or the hepatic triangular ligaments on the right, or during dissection of a large upper-pole tumor along the cephalad margin of the kidney.³² Pleural entry is usually recognized intraoperatively, and repaired at the end of the case. However, if ventilation is impaired during the case, venting the pressure in the pleural cavity with an angio-catheter may be necessary. Laparoscopic repair of most pleural injuries is advocated to minimize postoperative patient morbidity. Diaphragmatic injuries are more considerable, and primary full-thickness closure of the diaphragm using figure-of-eight non-absorbable sutures, placed under low insufflation pressures, achieves durable repair.^{21,33} Before securing the diaphragmatic sutures, carbon dioxide gas should be evacuated from the chest using a suction aspirator. An alternative approach is placement of a 6-Fr catheter with extra cut side-holes into the pleural space via the sixth intercostal space to aspirate residual air.³² For repair of diaphragmatic defects up to 2 cm, Gonzalez et al described suturing of a dual layer patch of non-absorbable polypropylene and absorbable polyglactin mesh.³⁴ Their intraoperative laparoscopic repair adheres to the known principles of diaphragmatic repair, including tension-free, air-tight closure with non-absorbable material. It is not uncommon to observe small amounts of residual pneumothorax postoperatively, which can be managed expectantly since carbon dioxide will be rapidly absorbed. However, if patients are symptomatic with respiratory insufficiency, a small chest tube may be placed for relief.

CONCLUSION

In the past quarter century laparoscopy has evolved from a basic diagnostic tool to a sophisticated therapeutic technique. Continued technological advancements and improved surgical skills have prompted

laparoscopists to undertake complex reconstructive procedures. Laparoscopy entails minimally invasive access into the abdomen, which is associated with a multitude of unique complications that are well described in the literature. However, once abdominal access is established, laparoscopic techniques of dissection and the principles of surgery have not changed drastically. The majority of injuries are analogous to those of open surgery. Complications continue to impact patient morbidity and convalescence. Indiscriminate application of laparoscopic techniques by inexperienced surgeons compounds the risk of serious complications. Most laparoscopic complications are largely avoidable, especially if patients are reviewed carefully, surgical indications are critically evaluated and individual surgeon's capabilities are assessed realistically. A significant decrease in complications has been documented with increasing surgeon experience, emphasizing the need for critical self-assessment. For complex reconstructive cases, familiarity with laparoscopic anatomy, increased individual experience, early recognition of the injuries, and immediate repair are all important factors for improving outcomes. A systematic approach to learning advanced laparoscopic techniques, and a gradual expansion of the surgical indications for laparoscopy should keep the complication rates to a minimum. Acquiring the procedural and laparoscopic skills to manage these complications is paramount in the face of this cutting edge, evolving technology.

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8 Laparoscopic and robotic pediatric surgery

Hillary Copp and Craig A Peters

Over 25 years have passed since Silber and Cohen first reported the application of laparoscopic surgery in pediatric urology for cryptorchidism.¹ Initially the practice of pediatric laparoscopic surgery was devoted to diagnostic procedures including the evaluation of cryptorchidism and intersex conditions. Over time the field has evolved to encompass extirpative surgeries, such as total and partial nephrectomy, and finally reconstructive operations, like pyeloplasty and ureteral reimplantation. While pediatric urologic laparoscopy is routinely performed at some academic centers, it has not become common practice because it demands a high level of technical skill, requiring significant investment of time to develop. With the advent of robotic technology the possibility for laparoscopy to become more widespread in the pediatric urologic community exists since robotic assistance may be able to facilitate the acquisition and maintenance of laparoscopic skills by the surgeon. It may assist the diagnostic laparoscopic surgeon in the transition to operative laparoscopy. Moreover, for the physician adept in laparoscopic surgery, the robot may be beneficial for the more complex and technically demanding reconstructive surgeries. In this chapter, we address general aspects of laparoscopic and robotic surgery as applied to the pediatric urologic patient and the specific laparoscopic and robotic approaches currently in practice.

GENERAL CONSIDERATIONS

Patient selection

General patient selection criteria for laparoscopic and robotic assisted surgery are equivalent. Most contraindications are relative and may vary depending on the surgeon's experience and comfort level. Common relative contraindications include obesity, or extensive previous intraperitoneal surgery. Although there are a handful of absolute contraindications these typically do not apply to the standard pediatric urologic patient. These include uncorrectable coagulopathy, intestinal obstruction, abdominal wall infection, massive hemoperitoneum, generalized peritonitis, and suspected malignant ascites.² Additionally, baseline patient issues

may be exacerbated by the physiologic effects of pneumoperitoneum. Therefore, patients with conditions such as obstructive airway disease or cardiac issues may not be able to tolerate this type of surgery and should be screened accordingly.^{3,4}

Patient age and size were originally thought to be limiting factors in regard to laparoscopic and robotic surgery. Yet, as we have become more comfortable in the techniques of laparoscopic and robotic assisted surgery we have applied these techniques to younger patients; in fact, some pediatric urologists that feel no minimum age limitation is warranted. Laparoscopic dismembered pyeloplasty has now been successfully performed irrespective of patient age.^{5,6} Moreover, it was originally thought that lack of tactile feedback with robotic assisted surgery would be problematic in smaller patients. However, with the appropriate training and experience this issue is less founded and has not seemed to disqualify pediatric patients from receiving robotic surgery.⁷

Patients as young as 2½ months have successfully undergone robotic assisted laparoscopic urologic surgery.⁸

Patient preparation

A limited bowel preparation is initiated 24 hours before surgery. This includes a clear liquid diet 24 hours prior to surgery and a glycerin suppository the night before surgery. For operations in the pelvis where a dilated rectosigmoid would significantly limit the working space a rectal tube is placed for decompression. The patient is then positioned according to the intended laparoscopic or robotic approach. With robotic surgery, patient positioning and bed adjustments must be finalized prior to docking.

Port placement

The same principles for port site selection apply to both standard laparoscopic surgery and robotic surgery, but are more critically important for robotic procedures in small children. The ports must be placed symmetrically in relation to the site of operation,

oriented about the central port, which is reserved for the camera. The camera is in line with the operative site creating the central axis. The two lateral working ports are placed equidistantly along a line perpendicular to the central axis and usually, but not always, in closer proximity to the operative site. Particularly in robotic surgery it is critical for the lateral working ports to be symmetric. If not, one of the robotic working arms will have limited range of motion or the movement of the camera arm will be inhibited.

Transperitoneal access is obtained through either a Hasson or Veress technique. The author prefers application of the Bailez technique, a modified Hasson approach, at the inferior portion of the umbilicus.⁹ A transverse skin incision is made and the umbilical scar is lifted. The subcutaneous tissue is dissected down to the peritoneum and fascial holding sutures are preplaced. The peritoneum is then entered bluntly under direct visualization. Pneumoperitoneum is established with insufflation of carbon dioxide at a rate of 6 l/min to a maximum pressure of 10–12 mmHg.

If retroperitoneal access via a lateral or prone approach is selected, the working space may be developed with a dilating balloon or by a combination of pneumo-dissection and blunt camera dissection. The initial port should be placed just lateral to the edge of the paraspinous muscle to limit inadvertent disruption to the peritoneum.^{10,11}

Complications

Although the literature is limited in this regard, the overall complication rate associated with laparoscopy in the pediatric urologic patient population has been reported to be between 2.7 and 5.38%.^{11,12} Yet, when minor complications, such as preperitoneal insufflation, that do not affect the ability to proceed with the operation are excluded, the complication rate decreased significantly to 1.18%.¹¹ Both the approach selected for initial access and the surgeon's level of experience with laparoscopic surgery correlated with the complication rate in a survey performed by the author.¹¹ Transperitoneal access obtained via the open or Hasson technique had significantly less associated complications than the Veress technique. This also corresponds with the adult laparoscopic literature where the complication rate decreased from 14% with Veress insertions to 0.9% with direct trocar insertions for laparoscopic cholecystectomy.¹³ While the authors did note a correlation between the experience level of the surgeon and the complication rate, Esposito et al did not. However, the

individual baseline, laparoscopic experience level of the physicians in the study by Esposito et al was greater than that of the physicians from the other survey.^{11,12} Additionally, Metzelder et al demonstrated that previous surgery had little influence on the subsequent feasibility of laparoscopic surgery in children.¹⁴ The conversion rate to open surgery was higher for the group with prior surgery versus those without prior surgery. The conversion rate decreased as the time out from prior surgery increased. Furthermore, the complication rate, when excluding the requirement for conversion to open surgery, did not increase in patients who had prior surgery and subsequently underwent laparoscopic surgery.

SPECIFIC APPLICATIONS

Upper tract surgery

The first reported pediatric laparoscopic nephrectomy was performed in 1992.¹⁵ This set the stage for the evolution of operative versus diagnostic laparoscopy in the field of pediatric urology. We now have applied the laparoscopic approach to all types of renal surgery from nephrectomies to pyeloplasties. Furthermore, robotic assisted laparoscopic surgery has also become a part of the armamentarium of approaches to renal surgery.

The set-up for both the laparoscopic and robotic assisted approach for renal surgery is similar. If transperitoneal access is elected, the patient is placed on a 30° flank wedge and secured to the table. The table is adjusted so the abdomen is flat and then the central port is placed at the umbilicus using the technique previously described. Typically the upper port is placed in the midline and the lower port is placed in the ipsilateral midclavicular line (Figure 8.1). In smaller children the lower port may need to be placed closer to the midline to maintain an adequate distance between the port entry and the operative area. Prior to placing the two additional ports the operator should insufflate the abdomen, identify the kidney, and approximate the location of the hilum verifying appropriate site selection for the working ports. After access is obtained the ipsilateral flank is rotated to an elevation of approximately 60°. If robotic surgery is to be performed the robot will be brought in from the ipsilateral shoulder and docked at this time (Figure 8.2).

For retroperitoneal access the patient may be placed in the lateral or prone position with the central camera port placed as previously described. The working ports are then placed lateral to the paraspinous muscle

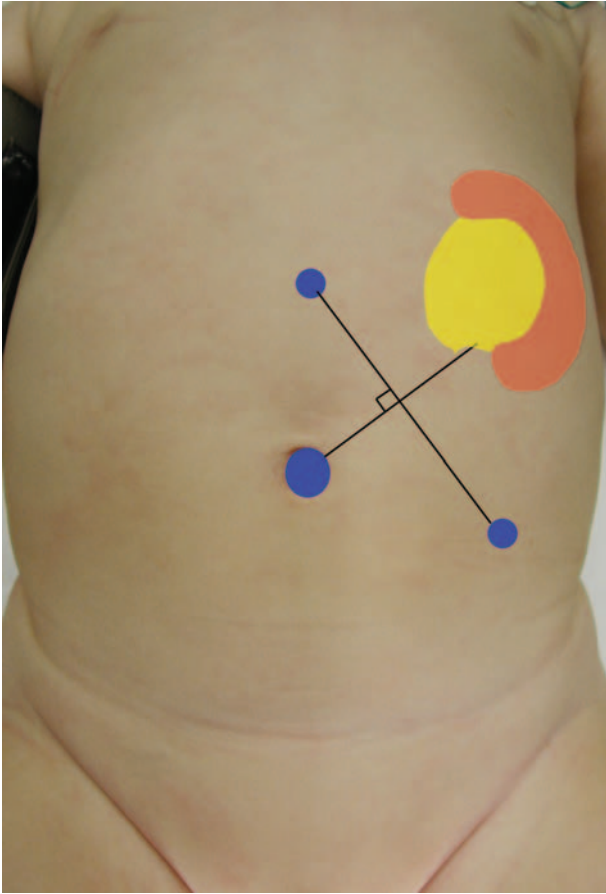


Figure 8.1 Port site location for laparoscopic renal surgery. The camera port is placed at the umbilicus. An imaginary line between the camera port and the operative site creates the central axis. The two working ports are placed in a line that is in closer proximity to the operative site that is perpendicular to and equidistant from the central axis.

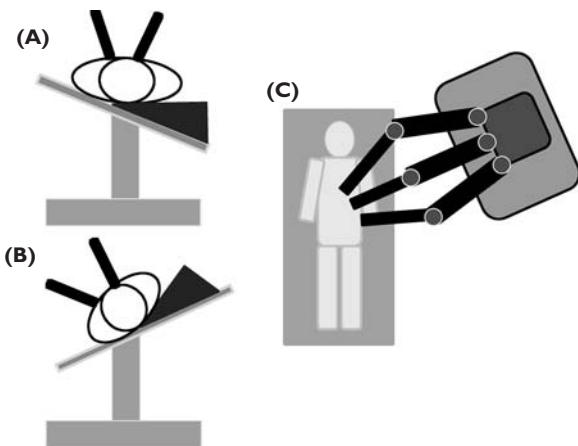


Figure 8.2 Robotic approach with renal surgery. Access is obtained with the patient on a 30° wedge and the abdomen flat. (B) The table is then rotated to elevate the ipsilateral flank to 60°. (C) The robot is directed in over the ipsilateral shoulder and docked.

above the iliac crest and in the anterior axillary line below the costal margin. Care must be taken during access to avoid the peritoneum. The authors prefer a retroperitoneal approach for standard renal laparoscopy and a transperitoneal approach for renal robotic surgeries, especially with younger patients. The main issue with the retroperitoneal robotic approach in smaller patients is the bulkiness of the robotic arms within the confines of the small extracorporeal working space along the flank.¹⁶ Moreover, for any renal surgery that also involves operating in the pelvis, a transperitoneal approach is preferred so that the robot does not have to be repositioned and re-docked.

Nephrectomy

Some surgeons believe laparoscopic nephrectomy is not warranted when the morbidity of the open procedure in children is minor, the incision is small, and the hospital stay is short. However, benefits in recovery time, pain medicine requirements, and cosmesis, especially in older children, make laparoscopic nephrectomy an attractive and reasonable option.^{17–19} Furthermore, the feasibility of laparoscopic transperitoneal nephrectomy in patients less than 1 year old has been demonstrated.⁶ Therefore, for younger children the approach taken may be a matter of surgeon preference. For those pediatric urologists already skilled in laparoscopy the robot does not offer a large technical benefit over conventional laparoscopy for a nephrectomy since no intracorporeal suturing is usually required. But, if the surgeon typically incorporates robotic surgery into his or her practice, he or she may prefer the use of the robot for its improved ergonomics and visualization over standard laparoscopy. For the less experienced laparoscopist wishing to expand his or her laparoscopic repertoire, the robot may facilitate this transition by improving visualization and dexterity.^{7,20}

The basic tenets of nephrectomy hold true regardless of whether the approach selected is laparoscopic versus robotic or retroperitoneal versus transperitoneal. The ureter is identified and traced up to the hilum. The hilar vessels should be dissected and ligated proximally to limit the number of branches encountered. Depending on the caliber of the vessels, clips or electrocautery may be used for ligation. The kidney is then freed from the rest of its attachments. Typically the specimen may be removed through the larger, central access port. The port site will occasionally need to be dilated or extended by incision. If a large specimen is being removed for benign reasons it can be morcellated and easily removed through the central port.

Partial nephrectomy

Laparoscopy may provide an advantage with partial nephrectomy due to the ability to obtain adequate exposure with minimal manipulation of the portion of the kidney that will be left behind.²¹ This is especially important in the pediatric population where the most common indication for partial nephrectomy is for a duplicated system and preservation of the remaining renal unit is crucial. If the affected ureter is to be resected to the level of the bladder a transperitoneal rather than retroperitoneal approach may provide improved visualization for the dissection down into the pelvis.⁷ The ureter to be removed is dissected free from its attachments, paying particular attention not to damage the remaining ureter. It is then followed up to the hilum where the demarcation between the two renal units can be identified. Traction may be placed on the ureter to the renal unit being removed to aid with the dissection between the two poles. The dissection between the two poles may be completed by monopolar electrocautery or harmonic scalpel. The remnant edge may be bolstered with suture to augment hemostasis and prevent urine leak.¹⁶ Depending on surgeon preference, gross inspection or administration of intravenous methylene blue may be performed to help identify any collecting system violation.^{16,19,21} Accordingly, any recognized entry into the remnant pole collecting system must be closed and any remaining collecting system from the removed pole should be cauterized.

Reports on both laparoscopic and robotic assisted partial nephrectomies have demonstrated that a minimally invasive approach is effective.^{11,19,22–24} A comparison by the authors between patients undergoing retroperitoneal laparoscopic versus open partial nephrectomy demonstrated similar operative times between the two techniques along with decreased postoperative narcotic requirements and shorter hospital stays in patients undergoing a laparoscopic partial nephrectomy.²⁵ A robotic assisted approach may offer further advantage intraoperatively by allowing for a more precise dissection between the two poles of a duplicated system due to its improved three-dimensional visualization and tremor filtered movements.²³ Furthermore, suture closure of the remnant pole collecting system is facilitated by the robot. Drain placement is operator dependent, but usually not required unless the patient is older or the case was complicated.¹⁶ The day following surgery the patient has the Foley catheter removed and is typically ready for discharge.

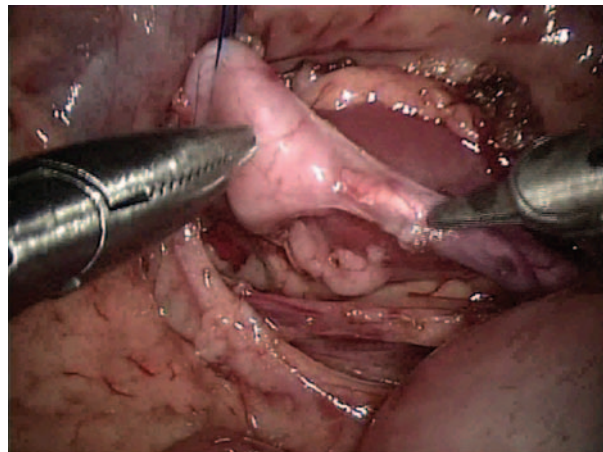


Figure 8.3 Placement of a hitch stitch in laparoscopic pyeloplasty. The renal pelvis is exposed and the ureteropelvic junction (UPJ) is adequately mobilized. Suture is driven through the abdominal wall, into the renal pelvis, and back out of the abdominal wall. The amount of tension placed on the stitch is adjusted extracorporeally to elevate the renal pelvis and improve exposure of the UPJ.

Pyeloplasty

Pyeloplasty may be performed through either a retroperitoneal or transperitoneal approach. For younger patients the transperitoneal approach provides a larger working space. If the operation is performed transperitoneally initial access to the kidney may be obtained transmesenterically or by reflecting the colon medially. A transmesenteric approach is more common on the left side due to the location of the renal pelvis in relation to colonic mesentery. A ureteral stent may be placed endoscopically in a retrograde fashion prior to the pyeloplasty or one may be placed intraoperatively in an antegrade fashion. The authors have found a hitch stitch in the renal pelvis to be vital for exposure (Figure 8.3).²⁶ To minimize trauma to the ureter the amputated portion of the renal pelvis is left attached to the ureter and used as a handle during the initial portion of the reapproximation. The ureter is spatulated laterally and the anastomosis is completed with two running monocryl sutures, one anterior and the other posterior, from base to apex. The redundant pelvis cephalad to the anastomosis is reapproximated to itself.

Pyeloplasty has been one of the more challenging applications of minimally invasive surgery due to its requirement of advanced laparoscopic skills in suturing a small target within a limited space. Despite this, those who have tackled either the retroperitoneal or transperitoneal laparoscopic approach to pyeloplasty have demonstrated successful outcomes, even in children as young as 1 month old.^{5,6,27,28} Bonnard et al demonstrated

decreased analgesic use and shorter hospital stays in a study comparing 22 patients undergoing retroperitoneal laparoscopic versus open pyeloplasty. However, the mean operative time for the laparoscopic approach was significantly longer than the open group, 219 minutes versus 96 minutes, respectively.²⁸

A natural progression to robotic assisted retroperitoneal and transperitoneal pyeloplasties evolved due to the improved control and accuracy the surgeon has with suturing. Several reports have indicated that results with the robotic approach are comparable to those with open surgery.^{8,29-31} In a retrospective study robotic-assisted pyeloplasty was compared with age-matched patients undergoing open pyeloplasty. Although operative times for robotic assisted surgery were longer, with more experience the times approached those of the open cohort. In addition the patients who underwent robotic assisted surgery had decreased postoperative pain medication usage and shorter hospital stays.^{8,29} Gettman et al evaluated 12 adults undergoing either transperitoneal laparoscopic or robotic assisted pyeloplasty. The use of robotic assistance decreased both overall operative and suturing times.³²

The patient is routinely ready for discharge the day following surgery. Prior to discharge the bladder catheter is usually removed. The child returns after approximately 2 weeks for stent removal. Follow-up thereafter is equivalent to that of standard open surgery.

PELVIC SURGERY

Laparoscopy provides excellent exposure to the pelvis. Its applications include intravesical and extravesical ureteral reimplantation, excision of Müllerian remnants and bladder neck surgery. In addition we have used a robotic approach for ureterocele excision with common sheath reimplantation, which supports the potentially wide application of this technique. Because pelvic surgery requires suturing in confined spaces the robot has made these operations more feasible as opposed to standard laparoscopy. For pelvic surgery it is helpful to place the patient in the Trendelenberg position to move the bowel out of the operative field. If a robotic approach is selected the robot is brought in from the foot of the bed and docked.

Müllerian remnant excision

Müllerian remnant excision is a technically challenging open surgery due to the depth and retrovesical location

of the remnant structures deep within the pelvis. Various open surgical approaches have been described; however, all require extensive mobilization of other structures in order to reach the site of interest. The laparoscopic or robotic assisted approach simplifies the surgery and decreases associated morbidity by providing excellent exposure with minimal manipulation of other tissues. Successful laparoscopic and robotic Müllerian cyst excisions have been reported in the literature.^{7,33}

Both minimally invasive surgical approaches are completed in a transperitoneal fashion. The bladder is lifted up and out of the field using a transabdominal hitch stitch. The dissection proceeds behind the bladder after an incision in the peritoneal reflection is made. Cystoscopic transillumination of the Müllerian cyst may aid in the dissection. Once the Müllerian remnant is dissected down to its connection with the urethra it is amputated, and the defect is sutured closed.

Bladder surgery

In 1994 the laparoscopic application of the Lich-Gregoir technique for repair of vesicoureteral reflux was described in humans by Ehrlich et al,³⁴ and has been reproduced by others.³⁵⁻³⁷ In 2005 laparoscopic cross-trigonal ureteral reimplantation with carbon dioxide pneumovesicum was reported.³⁸ However, laparoscopic ureteral reimplantation has not become common practice probably secondary to the technical challenge of the procedure. In contrast, robotically assisted antireflux surgery potentially appears more applicable to a larger number of surgeons. The increased feasibility of this approach is likely due to a number of characteristics afforded by the robot. These include magnification, three-dimensional vision, tremor-filtered instrument control, movement scaling, and wrist-like articulation of the instruments. Accordingly, robotically assisted vesicoureteral reimplantation surgery utilizing both approaches has materialized over the past few years in the pediatric population.²³

A laparoscopic or robotic assisted extravesical reimplant is performed through transperitoneal access in the manner previously described. The obliterated umbilical artery is identified and traced down along the abdominal wall and bladder side wall into the pelvis. The ureter is identified passing under and medial to the obliterated umbilical artery. The peritoneum over the ureter is then incised. In boys the vas deferens is identified and mobilized superiorly. Similarly, in girls the uterine ligament and pedicle is swept posteriorly. The ureter is mobilized adjacent to the bladder for 5 cm

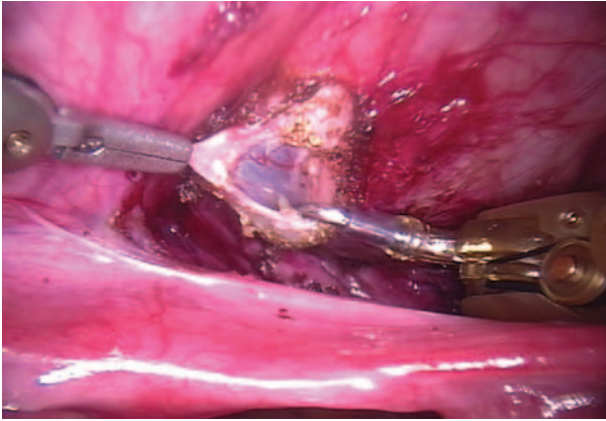


Figure 8.4 Submucosal tunnel creation in laparoscopic extravesical ureteral reimplantation. An incision is made in the detrusor muscle with cautery to the level of the mucosa. Flaps of detrusor muscle are peeled away laterally creating a trough in which the ureter is placed. The flaps are then wrapped over the ureter to create the submucosal tunnel.

down to the ureterovesical junction. A bladder hitch stitch can be placed to draw the bladder up and over to the contralateral side to improve exposure of the operative site.²³ With the bladder partially filled, a 2.5–3 cm incision in the detrusor muscle is made to the level of the mucosa. The detrusor muscle is then peeled away laterally creating flaps of muscle which will later be used to wrap the ureter to create its tunnel (Figure 8.4). The ureteral hiatus is mobilized in a Y-shaped fashion. All dissection is performed close to the ureter and careful attention is paid to not extend the dissection dorso-medially along the distal ureter.³⁹ The detrusor flaps are then wrapped around the ureter and approximated with 3-0 or 4-0 polydioxanone or polyglycolic acid; Vicryl® (Ethicon, Somerville, NJ) suture. No postoperative bladder catheter is necessary if significant mucosal injury does not occur.

In the transvesical approach a Foley catheter is placed and the bladder is filled with saline. The central camera port is placed into the dome of the bladder. A 12 mm suprapubic skin incision is made and then, through blunt dissection, the space of Retzius is entered and the bladder exposed. A 3-0 Vicryl suture is placed as a box stitch in the detrusor muscle for each port site. This delivers the bladder up into the incision and aids in trocar placement. The stitch also functions to keep the trocar in place during the surgery and facilitates closure of the cystotomies at the completion of the surgery. Yeung et al described a technique of passing sutures transabdominally into the bladder through two angiocatheters, one with a loop snare, to assist with placing the box stitch in the detrusor muscle.³⁸ The

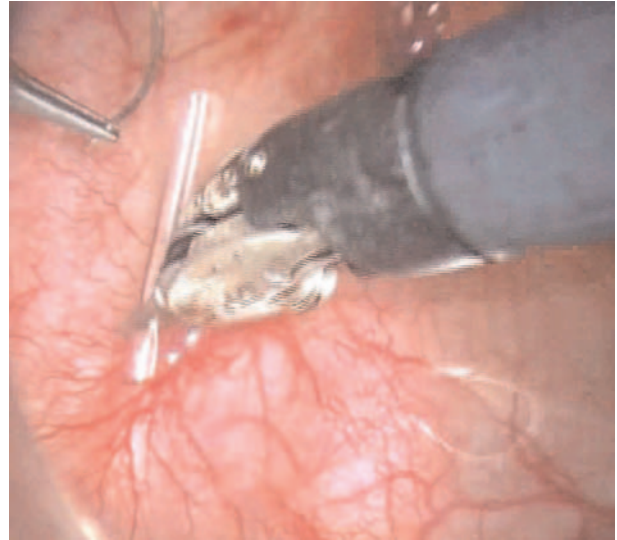


Figure 8.5 Robotic assisted laparoscopic intravesical ureteral reimplantation. A Foley catheter is placed and the bladder is filled with saline. The central axis port is placed transabdominally into the dome of the distended bladder. The two working ports are placed halfway between the pubis and the umbilicus equidistant from the central axis.

working ports are placed halfway between the pubis and the umbilicus equidistant from the central axis. All ports are placed using the Veress needle to introduce the VersaStep® (U.S. Surgical, Norwalk, CT) sheath and cannula. The camera port is the standard 12 mm port and the robotic working ports are 8 or 5 mm. The bladder is insufflated with carbon dioxide to a pressure of 8–10 mmHg, displacing the saline (Figure 8.5).

The transvesical operation then proceeds in a manner similar to the open cross-trigonal Cohen technique. The Foley catheter is left in the bladder and can intermittently be unclamped and placed on suction to clear the operative field. The ureter is stented with a 6 cm segment of a 5 Fr feeding tube. The stent is sutured to the ureteral meatus. It may then be used to place the ureter on traction to aid with dissection. The muscular hiatus is reduced in size and the new submucosal tunnel is made (Figure 8.6). The robot is particularly advantageous for this portion of the operation because of the articulation capabilities of robotic arms. This allows the scissors to be completely parallel to the trigone, thereby facilitating the formation of the tunnel. The ureter is pulled through its tunnel by the stent and then the stent is removed. The ureter is sutured in place and a 5 Fr feeding tube is passed to assess patency. Once the surgery is completed the pneumovesicium is evacuated. The ports are removed and the pre-placed detrusor sutures are used to close the cystotomies. The bladder catheter is left in place for 24 hours.

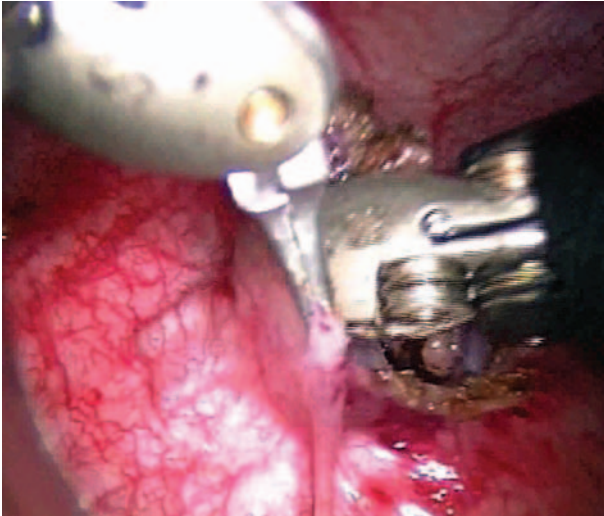


Figure 8.6 Submucosal tunnel creation in robotic intravesical ureteral reimplantation. The articulating capability of the robotic arms allows the scissors to be completely parallel to the trigone when creating the submucosal tunnel.

The experience with both laparoscopic and robotic assisted ureteral reimplantation is limited and there are very few outcome reports in the literature. Peters has reported at the AUA Annual Meeting, 2005, on his experience with 24 patients who underwent robotic assisted extravesical antireflux surgery. The reflux cessation rate was 87%. This is lower than the success rates of 92.5–98% quoted in the literature for open extravesical reimplants.⁴⁰ However, the author's comparative results in an age-matched, contemporary analysis demonstrated no statistically significant difference in resolution rates between robotic and open extravesical reimplants.

Reported experiences for transvesical laparoscopic or robotic assisted reimplantation are also few.^{38,41} The results of robotic assisted transvesical reimplantation in six patients have been reported.⁴¹ Five of six patients with follow-up had resolution of reflux. The operative time was longer than with open surgery, but with experience this has decreased. The hospital stay for patients ranged between 2 and 4 days. Further analysis is required to clearly define any advantages or disadvantages that the robotic approach may have versus the open operation.

MISCELLANEOUS

Orchidopexy

As little suturing is involved with orchidopexy robotic assistance does not offer a clear advantage over standard laparoscopy. Laparoscopic orchidopexy is a well-described

approach to the non-palpable testis. Debate exists as to whether open exploration should be selected first with conversion to laparoscopy if a testicle is not identified in order to prevent unnecessary laparoscopy.⁴² Along this line, initial groin exploration has been combined with subsequent transinguinal laparoscopy if no testicle was found.⁴³ However, an accepted and common approach to the non-palpable testis is initial diagnostic laparoscopy combined with therapeutic laparoscopic orchidopexy if an intra-abdominal testis is identified.⁴⁴ Specifically a primary orchidopexy or a staged Fowler-Stephens orchidopexy can be performed to bring the testicle down to the scrotum. In any patient over age 2 a staged Fowler-Stephens is recommended due to the increased difficulty with bringing these testes down into the scrotum.¹¹ A staged orchidopexy is also preferred if the distance between the testis and ipsilateral internal ring is greater than 2 cm.⁴⁵ Results from a multi-institutional analysis of laparoscopic orchidopexy provide evidence that a single stage Fowler-Stephens operation should be avoided as it has a significantly higher atrophy rate of 22.2%. In comparison the atrophy rate for a primary orchidopexy or a staged Fowler-Stephens technique is significantly less at 2.2% and 10.3%, respectively.⁴⁴

The 2 or 3.5 mm endoscope is passed through the appropriately sized VersaStep sheath at the umbilicus. The working ports are 3.5 mm and located in the ipsilateral upper quadrant and the contralateral lower quadrant. If a staged Fowler-Stephens is to be performed the testicular vessels are isolated and clipped, and this can be performed with only one working port if preferred. For primary orchidopexy the peritoneum lateral to the testis is incised and the testicle is mobilized. A triangular web of peritoneum remains between the testicle, the spermatic vessels, and the vas deferens. The authors choose to incise this and dissect cephalad along the spermatic vessels thereby providing more mobility of the testicle. A path above the pubis and between the bladder and medial umbilical ligament is developed into the scrotum. An incision is made in the scrotum over the palpable laparoscopic instrument and the instrument is passed through the dartos to the outside. A vascular clamp is then fed over the instrument and as the laparoscopic instrument is pulled back into the abdomen the vascular clamp follows. The clamp is then used to grasp the mobilized testis and deliver it down to the scrotum. The testis is secured in the scrotum.

Continent stoma construction

The Mitrofanoff technique has been described using both a laparoscopic^{46,47} and robotic approach.^{16,48}

A 10–12 mm camera port is placed at the umbilicus and two 5–8 mm ports are placed below the umbilicus in the mid-clavicular line bilaterally. The appendix is identified and the ascending colon is mobilized. The appendix is amputated at its junction with the cecum. A cuff of cecum is left with the appendix to facilitate stomal formation and prevent subsequent stomal stenosis. The cecum is closed in two layers with a standard imbricating purse-string suture. After filling the bladder and selecting the site of implantation a 4 cm longitudinal incision down through the detrusor muscle to the level of the mucosa is made. A button of mucosa from the distal extent of the dissection is removed and the appendix is anastomosed to the bladder. The remaining proximal appendix is then placed into the mucosal trough and the bladder muscle is wrapped overtop, creating the submucosal tunnel for continence. The base of the appendix is brought up through the umbilicus or lower abdomen, and a V-flap technique is used to create the stoma. Docimo has advocated a combined laparoscopic and open approach by mobilizing the colon laparoscopically thereby permitting use of a smaller, transverse incision to perform the appendicovesicostomy. A comparison between laparoscopic assisted and open Mitrofanoff technique by Cadeddu and Docimo showed that patients who underwent the laparoscopic approach had a significantly faster recovery.⁴⁶

Casale et al retrospectively compared a laparoscopic approach to an antegrade continence enema (ACE) in six patients with 20 patients who underwent an open ACE procedure.⁴⁷ Laparoscopic mobilization of the appendix and colon is performed as described above with the Mitrofanoff technique. Leaving the appendix in situ, the appendiceal valve mechanism is then reinforced with imbricating serosal sutures. This can be accomplished entirely intracorporeally or with a combined extracorporeal technique if laparoscopic suturing is not possible. The appendix is delivered through the umbilical port, patency of the appendix is tested, and a stoma is created. The abdomen is re-insufflated and the cecum is then fixed to the abdominal wall to prevent tension on the appendix. Early results for the laparoscopic approach demonstrated decreased postoperative pain and hospital stay versus the open approach. Cadeddu et al also demonstrated improved postoperative cosmetic appearance with a laparoscopic approach.⁴⁶

Bladder augmentation

Pure laparoscopic augmentation approaches have been described but the operative times have been extensive due to the high degree of technical difficulty.^{49,50}

Therefore, a combined laparoscopic and open approach is performed to decrease morbidity and simultaneously limit the length of the operation.⁵¹ Typically the mobilization and harvesting of the bowel segment is done laparoscopically. The reconstruction is then accomplished through a smaller, less morbid incision in the lower abdomen. Using this combined approach operative times have matched those of the open reconstructive operations.

SUMMARY

Over two and half decades ago the first pediatric urologic laparoscopic surgery was reported in the literature. The field has evolved from its initial diagnostic applications to encompass some of the more complex reconstructive surgeries within pediatric urology. Due to the wide variety of reconstructive procedures performed by any given pediatric urologist, acquiring proficiency in laparoscopic surgery for the pediatric urologist has been challenging. Those who perform the more advanced laparoscopic surgeries such as pyeloplasties or ureteral reimplants are largely located in a small minority of academic centers. Furthermore, there has been a resistance to the application of minimally invasive technology in this population, since its benefits are difficult to prove when patients recover rapidly with open surgery and operative success is high. However, if robotic assistance can make the application of this technology a reality for a larger number of surgeons and the results are equivalent, then a minimally invasive approach to various pediatric urologic surgeries may become the new standard, or an important part of the surgical armamentarium.

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9 Urologic applications of robotic surgery

Patrick E Davol, Brant R Fulmer, and Daniel B Rukstalis

INTRODUCTION

The introduction of robotic technology for applications in surgery has been received with enormous enthusiasm. Even with obstacles such as acquisition costs and maintenance, robotic surgery is becoming widely accepted as a desirable alternative to traditional minimally invasive techniques. Precise instrument movements, three-dimensional visualization, and a magnified field of view are the primary reasons that robotic assisted laparoscopic surgery is a natural extension of conventional laparoscopic techniques. Moreover, in some types of cases, robotic surgery has even had a more accelerated evolution skipping the conventional laparoscopic technique altogether. A defined advantage of robotic surgery appears to be that it allows individuals who are not expert laparoscopists to perform complex minimally invasive techniques using the robot as an interface. This levels the playing field for traditional open surgeons to embrace the new robotic technology with little or no laparoscopic skills.

The goal of this chapter is to present an overview of the robotic technology and its applications in performing urologic procedures. As will be seen below, this is a story of rapid and ongoing clinical evolution that has largely been driven by the personal career commitment to pioneering the new technology of robotic assisted laparoscopy and broadly applying it to urologic care.

HISTORY OF ROBOTIC SURGERY

The development of robotic technology for surgical applications has evolved down two essentially different pathways. The first applications of robotics in surgery were 'precise path systems' and essentially relied on the robot performing a preprogrammed set of precise maneuvers. Examples of this application in urology are the endoscopic Surgeon Robot for Prostatectomies (Probot),¹ and the PAKY device for percutaneous renal access.² In contradistinction, the second evolutionary path is the concept of a 'master-slave' system where the robot is given a precise set of commands through an interface, and carries out a precise controlled action in real time controlled by the operator. The AESOP

Table 9.1 da Vinci surgical system Food and Drug Administration clearance dates

	Procedure
May 2000	Mitral valve repair
July 2000	Cholecystectomy
March 2001	General non-cardiac thoracoscopic involving the lungs, esophagus, and internal thoracic artery
June 2001	Laparoscopic prostatectomy
April 2005	Gynecologic procedures

monotasking robot arm was the earliest master-slave technology, and is still used extensively as an automated laparoscopic assistant.³ The next step in the evolution of master-slave technology came in the form of the Zeus® (Computer Motion) and the da Vinci® (Intuitive Surgical). Though initially developed by the United States Department of Defense for use in military surgical battlefield applications, computer assisted, master-slave type robotic technology has been converted for civilian use by the entrepreneurial efforts of these two rival corporations. Each company had parallel development of a robotic interface for use in human surgical applications. Both systems relied heavily on a laparoscopic patient-robot with instruments placed through small trocars placed through the patient's skin with the working field being developed predominantly by insufflation of the peritoneal cavity with carbon dioxide. Eventually, the corporate acquisition of Computer Motion by Intuitive Surgical, made Intuitive Surgical the sole provider of advanced robotic technology for use in human surgical procedures. Pertinent Food and Drug Administration (FDA) clearance dates for specific procedures can be found in Table 9.1.

THE DA VINCI ROBOTIC SURGICAL SYSTEM

The initial da Vinci robotic systems were produced using a three-arm configuration with a camera port and two triangulated working ports. A later development was the addition of a fourth arm that can be utilized to add another working port for instruments or retractors.

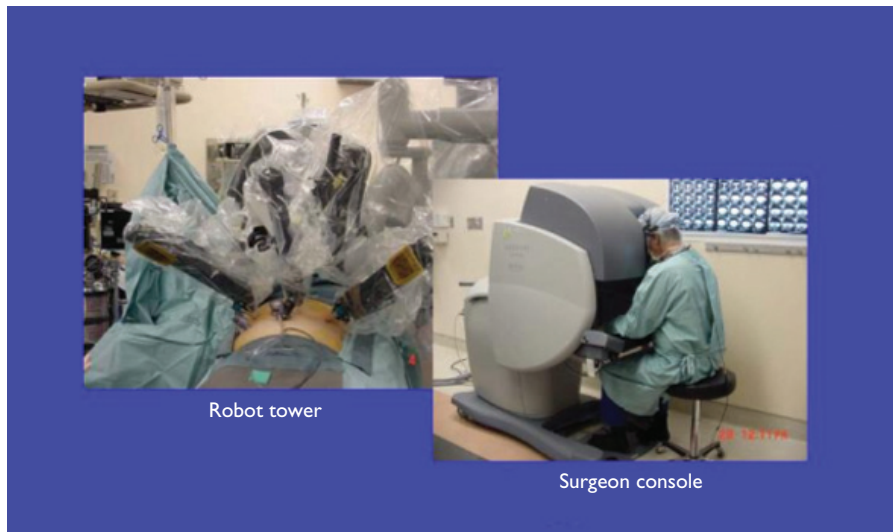


Figure 9.1 Da Vinci robotic surgery system.



Figure 9.2 Da Vinci robot–surgeon console interface.

The four arm da Vinci robotic surgical system is pictured in Figure 9.1. The most recent evolution involves the introduction of a second-generation robotic surgery system dubbed the da Vinci S that has several ergonomic and functional improvements over its predecessor. The surgeon interface is a combined three-dimensional monitor and surgeon control station shown in Figure 9.2. The surgeon can sit comfortably in the ergonomically designed console and control the robotic camera and arms using the hand controls. The EndoWrist® articulated instruments are designed with seven degrees of freedom: in, out, left, right, up, down, rotational axis, pitch, yaw, and grip. The bidirectional articulation and grip mimic the actual hand and wrist movements of the surgeon. The camera is positioned

centrally between the two instruments to create the illusion of operating directly on the patient. Foot controls are also available for camera focus and movement, cautery activation, and toggling between individual robotic arms in the four arm robotic systems. The available robotic instrumentation is quite diverse and has the full laparoscopic instrument armamentarium while providing more degrees of movement than the human wrist. Several representative instruments are shown in Figure 9.3. Movement of these instruments can be performed in a scaled manner with precise adjustments, and the surgeon interface serves to maximize ergonomics while minimizing unwanted operator inputs such as tremor. This has the potential of improving both surgeon comfort and patient safety.



Figure 9.3 Representative examples of robotic instruments.

ROBOTIC ASSISTED LAPAROSCOPIC RADICAL PROSTATECTOMY

Laparoscopic radical prostatectomy is arguably one of the most challenging conventional laparoscopic procedures in urology. The technically demanding nature of the procedure and the long learning curve has kept this procedure essentially limited to large volume laparoscopic centers of excellence. These factors combined with the high prevalence of prostate cancer made radical prostatectomy a procedure ripe for the application of a new technology like robotics. Use of robotic technology for laparoscopic prostatectomy has made this a rapidly and extensively utilized procedure for localized prostate cancer. In addition, the development of robotic technology has allowed even non-laparoscopically trained urologists to perform this procedure with a more favorable learning curve and easier transition from open technique.⁴ The basic procedural steps are identical for the laparoscopic and robotic assisted laparoscopic procedures, but the robot interface has served to enhance the surgeon's ability to perform the typically complex portions of this procedure such as the nerve sparing and the urethral vesical anastomosis.

Due to limitations in the length of instrumentation and also the inherent small working space that is present within the pelvis, patient selection is the key to successful outcomes from this and other minimally invasive approaches. The key to the performance of laparoscopic surgical intervention of any variety is accurate visualization of the surgical field and

adequate working space. Patients with a very large prostate of greater than 100 g are not ideal as the prostate is difficult to manipulate in the narrow confines of the pelvis. Patients that are morbidly obese or who demonstrate small narrow pelvic anatomy are not ideally suited for this approach and certainly represent a distinct technical challenge. For similar reasons, patients with a history of previous abdominal surgery or pelvic surgery may not be ideal candidates, as it is very difficult and potentially dangerous to achieve adequate access with multiple pelvic adhesions. With increased experience, these more challenging patients can be included as surgical candidates, but it is not recommended that these patients be in the early experience for a surgeon learning this technique.

DESCRIPTION OF ROBOTIC ASSISTED LAPAROSCOPIC PROSTATECTOMY PROCEDURE

The patient should be in the high lithotomy position with maximal cephalad down positioning of the table. This head-down position allows for gravity to act facilitating the natural retraction of the tissues of the pelvis. The initial laparoscopic peritoneal access is obtained using an infraumbilical incision. A Veress needle or Hasson type trocar is used to establish pneumoperitoneum and to facilitate the laparoscopic survey of the abdomen. Carbon dioxide is then insufflated into the abdomen to achieve pneumoperitoneum. If a Veress needle was used for initial access, this is replaced by a

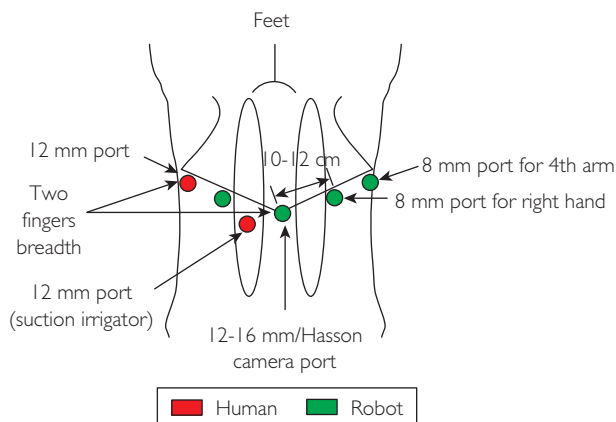


Figure 9.4 Trocar placement for robotic assisted laparoscopic radical prostatectomy.

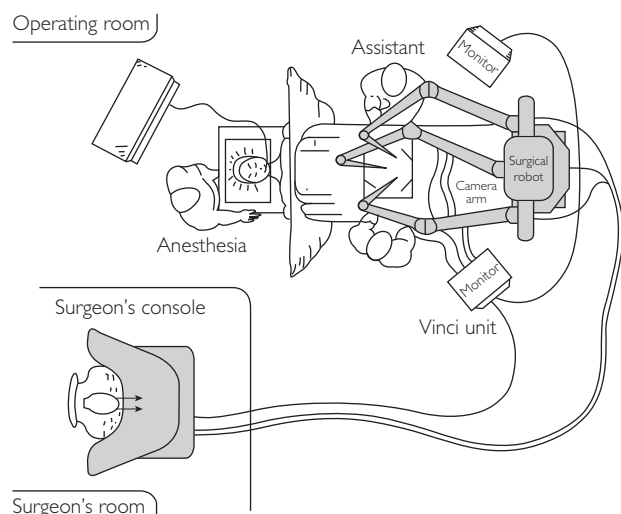


Figure 9.5 Operating suite set-up for robotic assisted laparoscopic radical prostatectomy.

12 mm radially dilating laparoscopic trocar. Two additional 8 mm robotic trocars are placed in a symmetric fashion approximately two finger breadths below and 10–12 cm lateral to the umbilical trocar. These trocars are used for placement of the robotic arms into the peritoneal cavity. At this point in a position approximately 8 cm lateral, roughly corresponding to the midaxillary line, another set of trocars is placed bilaterally. On the right, an 8 mm robotic trocar is placed for the fourth robotic arm. On the left, a 5 mm trocar is positioned between the camera arm and the left robotic arm. One additional trocar, for a total of six, is placed in a position 8 cm lateral and inferior to the left robotic arm. The overall effect is one of a fan-type distribution shown in Figure 9.4. At this point, the da Vinci robot is moved into position at the foot of the table with the central tower roughly in line with the

patient's pubic symphysis and the robot docked into position. Room setup, robot location, and staff positioning are shown diagrammatically in Figure 9.5.

Initial dissection is undertaken at roughly the level of the vas deferens lateral to the medial umbilical ligament. An inverted U-shaped incision of the peritoneum is then undertaken and the relatively avascular plane between the bladder and the pelvic side wall is identified with careful dissection to allow inferior mobilization of the bladder and identification of the puboprostatic ligaments and lateral endopelvic fascia. Care is taken to adequately mobilize the bladder bilaterally in order to allow for a tension free urethrovesical anastomosis. The lateral endopelvic fascia is then incised from the apex of the prostate cephalad to the prostatovesical junction. Blunt dissection is used to sweep the levator fibers laterally and to identify the lateral wall of the prostate and the prostatico-urethral junction. Minimal electrocautery is used in this location in order to reduce any damage to the levator fibers and the external urinary sphincter. The dorsal venous complex is then ligated and divided.

Electrocautery is used to incise the anterior bladder neck and the plane between the prostate and the bladder is developed. This plane can be developed by starting in the midline and working laterally, or optionally starting laterally and working to the medial border. Once the bladder has been entered it can be dissected free laterally. A particular area of difficulty is in individuals who have a large median lobe. This requires incision of the mucosa over the median lobe and careful dissection posterior to the prostate in order to achieve the appropriate plane of dissection. At this point, the ureteral orifices are identified bilaterally and care is taken to divide the posterior prostatic urethra and bladder neck in an area distal to the ureteral orifices.

Once the perpendicular plane of dissection has been taken down through the level of the posterior bladder wall, the superficial Denonvilliers' fascia is identified and incised and vas deferens is divided bilaterally. The seminal vesicles are dissected completely from the surrounding tissue using a combination of sharp and blunt dissection. Once the seminal vesicles and vas deferentia are dissected free, the posterior layer of Denonvilliers' fascia is then incised and the plane between the prostate and the rectum is dissected. The key to development of the plane between the prostate and the rectum lies in identifying the perirectal fat inferiorly and leaving a plane of fat over the serosa of the rectum. Once the plane of dissection is carried down to the level of the apex of the prostate in the inferior aspect, attention can be turned to the bilateral prostate pedicles.

When viewing the prostate from a superior aspect, the vascular pedicles are present in approximately the 5 o'clock and 7 o'clock positions directly distal to the bladder neck. The lateral pedicles to the prostate are then identified along with the neurovascular bundles, which run in an approximately perpendicular direction to the orientation of the prostate pedicle. If a nerve-sparing prostatectomy is to be performed, care is taken during this portion of the procedure to avoid the lateral neurovascular bundles. The cautery is minimized to avoid any direct extension of either electrical current or heat to the neurovascular bundles. A modification of this procedure involves taking a 'veil' of periprostatic fascia to avoid any damage or traction to the neurovascular bundles. The pedicles are taken and the dissection is performed from superior to inferior, and using this technique, the neurovascular bundle is mobilized laterally. In certain circumstances there may be small areas of bleeding in the area of the neurovascular bundle and these are usually treated with direct pressure rather than attempts at applying electrocautery because of the risk of injuring the neurovascular bundle.

The previously ligated dorsal venous complex is then divided using robotic scissors. Careful dissection of the dorsal venous complex away from the urethra and prostatic apex allows for the development of excellent urethral length again aiding a tension free urethrovesical anastomosis. The urethra is then divided sharply distal to the prostatic apex. Once the prostate has been completely freed from its attachments, it is removed via a laparoscopic retrieval sack, and attention can be turned to the urethrovesical anastomosis.

Several different methods have been undertaken to perform the urethrovesical anastomosis. The keys to success with urethrovesical anastomosis rely on minimizing any tension between the bladder neck and the urethra. Our preferred technique is to use a double armed running suture of 3-0 Monocryl. One strand is dyed and one strand is undyed, allowing for adequate identification of both edges of the suture. The anastomosis is completed by beginning suturing in an inside-out fashion on the bladder neck at approximately the 6 o'clock position. The suture is then carried in a running fashion clockwise to approximately the 12 o'clock position at which time the needle is removed and a needle driver is used to hold traction on this suture to prevent any unraveling of the suture. The non-dyed end of the double-armed suture is then grasped by its needle, and again a running suture line is performed to complete the right side of the urethral vesicle anastomosis. A new 20 Fr Foley catheter is placed in the bladder with the balloon inflated. The two ends of the suture are carried back to the midline, and tied using the robotic needle drivers. This method of

anastomosis allows for excellent mucosa-to-mucosa approximation of the urethra and bladder neck. The anastomosis is then checked to make sure that it is watertight by instilling approximately 180 ml of sterile saline into the bladder. We place a temporary 15 Fr Jackson Pratt drain in the renal pelvis with care taken not to place this directly in the area of the anastomosis. The robot is then undocked from the field and the Endocatch bag containing the prostate specimen is removed through the umbilical trocar.

Patients generally stay in the hospital for 24–48 hours. Patients are generally seen in approximately 5–7 days and undergo a cystogram to ascertain the integrity of the urethrovesical anastomosis. If there is no extravasation noted on the cystogram in the area of the urethrovesical anastomosis, the Foley catheter is removed.

RESULTS OF ROBOTIC ASSISTED LAPAROSCOPIC RADICAL PROSTATECTOMY

To be accurate, outcome measures after any of the available treatments for clinically localized prostate cancer must include operative data, parameters assessing oncologic efficacy of the procedure as well as a measurement of post-treatment side-effects effecting functional status. Oncologic efficacy is generally gauged based upon measurement of evidence of biochemical recurrence. Therefore, the prostate specific antigen (PSA) level serves as a surrogate serum measurement for oncologic success of the operation. Additional information can be gained from the postoperative final pathologic review and generally allows fairly accurate prognostication about the success of the procedure and risk of recurrence. Unfortunately, due to the rapid evolution of this procedure, there is a paucity of long-term (>5 year) data regarding the oncologic outcomes of this procedure.

By far, the largest series to date describing the use of the da Vinci surgical system for laparoscopic assisted radical prostatectomy comes from the Vattikuti Institute of Urology at the Henry Ford Hospital in Detroit. The most recent published data from Menon et al describe their experience with 2652 robotic prostatectomies. There were 1142 patients who had at least 1 year of follow-up and the salient data from this group are presented below.⁵

Functional outcomes

The incontinence rate was very low with only 0.8% of men reporting total incontinence at 12 months. The

median duration of incontinence was reported to be 4 weeks. Of patients who were potent prior to surgery, 51% reported a return to baseline function. Perhaps a more telling measure of outcome was the reported 93% intercourse rate reported for the 1-year group.

Cancer control outcomes

The biochemical recurrence rate was reported to be 2.3% in the group with 1 year or more of follow-up, and the actuarial 5-year biochemical recurrence rate was 8.4%. Although the Vattikuti Institute enjoys the largest experience and reports excellent functional and oncologic outcomes, a recent meta-analysis of the published literature for robotic assisted laparoscopic radical prostatectomy suggests that additional studies are needed.⁶ The authors concede that the robotic prostatectomy is feasible, safe, produces less blood loss, and shortens hospital stay. They conclude that the oncologic efficacy data are not quite mature and suggest that postoperative continence and potency data are interesting but need further elucidation.

ROBOTIC ASSISTED NEPHRECTOMY, PARTIAL NEPHRECTOMY, AND NEPHROURETERECTOMY

Laparoscopic nephrectomy is a widely utilized procedure that has become the mainstay of minimally invasive extirpative renal surgery. There are many advantages to this approach not least of which is sparing the patient the morbidity of a large flank incision. Therefore, given the relatively extensive penetration of this technique, the paucity of data that exists for the use of robotic technology for this application is surprising. The first animal studies appeared around 2000,⁷ and Guillonnet al reported the human robot assisted laparoscopic nephrectomy in 2001.⁸ Since that time, there has been a generalized hesitancy to utilize the robot for performing nephrectomy. Anecdotally, opponents of this technique cite the robot as an unnecessary expense that adds little to improve the procedure. In addition, the sweeping movements needed for nephrectomy and nephroureterectomy would seem to confound the typically cited strengths of the robot including magnified field of view and ability to perform complex dissection in a small operative field. By way of an example, these perceived weaknesses could serve to easily explain why this technology is not widely utilized for radical nephrectomy. The not uncommonly large specimen and the wide dissection field certainly can make this procedure very challenging.

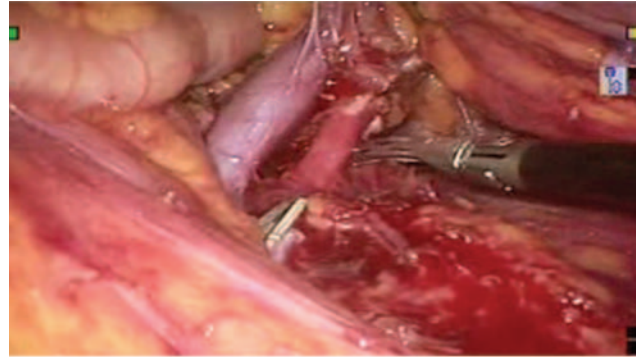


Figure 9.6 Renal hilum view during robotic assisted laparoscopic donor nephrectomy.

At some centers including ours, however, the da Vinci robotic technology has been broadly applied, and laparoscopic simple, radical, donor, and partial nephrectomy are performed routinely by several skilled robotic surgeons. This is not to suggest that some of the criticisms are unfounded. It is certainly more challenging to maneuver the robot from the upper pole of the kidney to the distal ureter, and doing so requires precise patient and robotic positioning. The advantage, however, of using the robot is the excellent three-dimensional visualization of the renal hilum and the precise dissection afforded by the robotic interface. The introduction of harmonic scalpel and advanced plasmakinetic bipolar technology has also served to give the surgeon a similar armamentarium to conventional laparoscopy and make nephrectomy overall safer for the patient.

One procedure where the potential advantages of using the robot are slowly being realized is in donor nephrectomy. In several centers, including our own, robotic assisted laparoscopic living donor nephrectomy has been pioneered and has supplanted either conventional or hand assisted laparoscopic technique for renal donation.^{9–11} In donor nephrectomy, the strengths of the robotic technology are exploited with the ability to meticulously dissect the renal hilum with minimal manipulation of the renal specimen. The intraoperative view of the renal hilum during robotic assisted laparoscopic donor nephrectomy is shown in Figure 9.6. Robot and patient positioning for robotic assisted laparoscopic nephrectomy are shown in Figure 9.7, and port configuration is depicted schematically in Figure 9.8.

In our early experience, 27 patients have undergone robotic donor nephrectomy at our institution. Mean patient age was 33.5 years (range 18–51). Operative parameters are summarized in Table 9.1. Mean operative time was 179.9 minutes (range 103–237) and

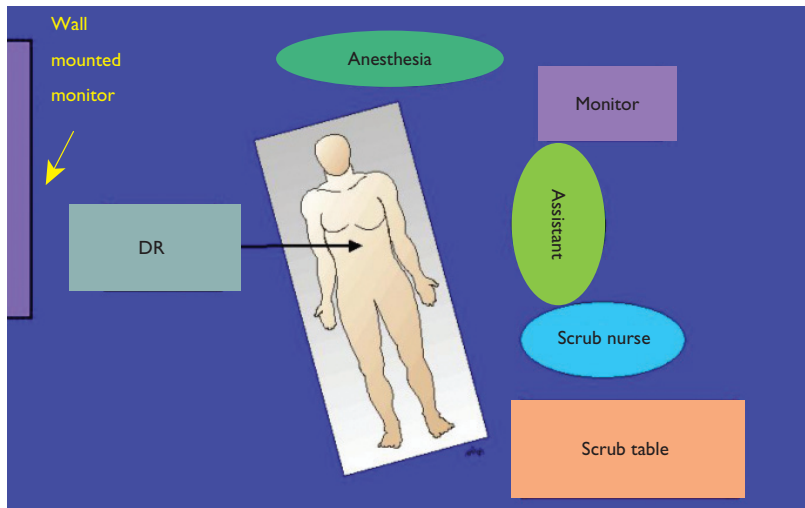


Figure 9.7 Robot and patient position for right robotic assisted laparoscopic nephrectomy. DR, da Vinci robot.

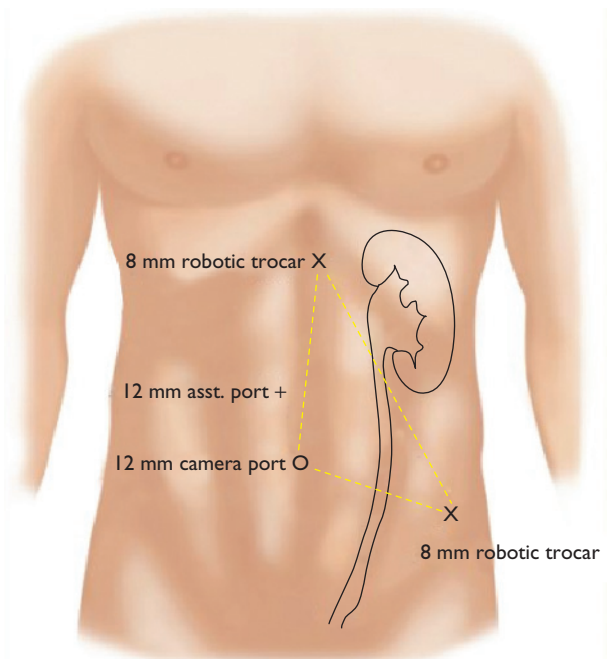


Figure 9.8 Port placement for left robotic assisted laparoscopic nephrectomy.

mean robotic dock time was 82.4 minutes (range 63–115). Mean blood loss was 105 ml (range 50–200), and warm ischemic time was less than 30 seconds in all cases.⁹

There are also emerging reports with small series of robotic assisted laparoscopic partial nephrectomy that show this to be a safe technique with operative parameters consistent with conventional laparoscopy.^{12–15} In the case of robotic partial nephrectomy, the robot is particularly well suited for suturing the collecting system as well as achieving renal parenchymal hemostasis.

Published series describing the initial experience with robotic assisted laparoscopic radical nephrectomy and nephroureterectomy are also emerging, though

most series are small ‘proof on concept’ studies rather than large clinical series.^{16–18} In our experience with robotic assisted laparoscopic radical nephrectomy, we have found the robot to be particularly helpful with control of aberrant vasculature, and feel the robotic interface with its three-dimensional magnified view is also well suited for the radical anatomic dissection of the kidney. The same is true for radical nephroureterectomy, which we also perform routinely in our practice. Challenges inherent to kidney dissection such as wide movements of the robotic arms and maneuvering the large renal units are relatively easily overcome with increased experience with the robot interface.

ROBOTIC ASSISTED LAPAROSCOPIC PYELOPLASTY

Commensurate with the ever-expanding role of minimally invasive techniques in urologic surgery, there is a growing body of literature supporting the role of laparoscopic pyeloplasty in the management of ureteropelvic junction (UPJ) obstruction. Multiple reports now demonstrate the efficacy and safety of this technique, as well as reductions in morbidity and hospital stay when compared with traditional open approaches.^{19–22} However, the procedure is technically demanding, as intracorporeal suturing and advanced laparoscopic techniques are required. It therefore makes an ideal application for modern robotic technology, with its remarkable freedom of movement capabilities and improved visualization, which have already revolutionized radical prostatectomy.

The first report citing use of robotic assistance for laparoscopic pyeloplasty included utilization of robotic arms to position the laparoscope, as well as to facilitate exposure with simple retraction.²³ The first

Table 9.2 Published outcomes for robotic assisted laparoscopic pyeloplasty

	Gettman et al ²⁷	Bentas et al ²⁸	Peschel et al ²⁹	Peters et al ³⁰	Patel et al ³¹
No. of patients	9	11	49	22	50
Mean age (months)	NA	NA	NA	107	31
Operative side					
Right	8	6	NA	8	NA
Left	1	5		14	
Primary UPJ obstruction	7 (78%)	11 (100%)	39 (79%)	NA	45 (90%)
Type of repair	AH	AH	AH (40), FP (2), YV (7)	AH	AH
Mean operative time (min)	138.8	196.8	124*	NA	122
Mean suturing time (min)	62.4	NA	NA	NA	20
Mean blood loss (ml)	<50	NA	<50	NA	40
Open conversion	0	0	0	0	0
Reintervention	1 (11.1%)	0	1 (20.4%)	2 (9.1%)	0
Complications	1 (11.1%)	0	1 (20.4%)	2 (9.1%)	1 (2%)
Mean length of hospital stay (days)	4.7	5.5	NA	NA	1.1
Mean follow-up (months)	4.1	21	7.4	13.8 [†]	11.7
Success	100% [‡]	100%	100%**	94.4%	100%

* Operative time included set-up of the robot.

[†] Follow-up available for 18 patients; mean follow-up with imaging at 6.6 months.

[‡] Follow-up available for five patients.

** Follow-up available for 41 patients.

UPJ, ureteropelvic junction; AH Anderson-Hynes; FP, Fenger-plasty; YV, YV-plasty.

report detailing use of a robot to actually perform a pyeloplasty was by Sung et al, who randomized swine to either unstented robotic assisted pyeloplasty using the Zeus robotic system or conventional laparoscopic pyeloplasty. Outcomes including operative time, anastomotic suturing time, and water-tightness were similar between the two groups.²⁴ This work was followed by further animal studies comparing the da Vinci and Zeus robotic systems. In a study of 14 swine undergoing several renal procedures including pyeloplasty, these investigators reported that the da Vinci robotic group had shorter total operating room time, anastomotic suturing time, and a greater number of suture bites per ureter compared with animals undergoing procedures with the Zeus system.²⁵

The pioneering animal studies with robotic pyeloplasty in swine led to the eventual application of similar techniques in humans. The first reported series of robotic assisted pyeloplasty in humans described an adaptation of previously described laparoscopic techniques which were applied using the da Vinci robotic system.²⁶ In this report, Gettman et al performed Anderson-Hynes dismembered pyeloplasty in nine patients. Patients did not undergo pre-defined selection criteria, and the series included two patients with secondary UPJ obstruction after failed endopyelotomy. This demonstrated the feasibility of the technique and argued favorable efficacy, although imaging data were available on only five patients at a mean follow-up of 4.1 months. The same group reported

later that year on a subset of patients undergoing robotic assisted laparoscopic pyeloplasty whose patient and surgical characteristics were compared with a cohort of patients in whom conventional laparoscopic pyeloplasty was performed. They reported decreased operative time using the da Vinci system, although other characteristics were similar.²⁷

Since the original series by Gettman, several authors have reported encouraging results with robotic pyeloplasty, with increasing length of follow-up^{28–31} (Table 9.2). Additional studies have compared conventional laparoscopic with robotic assisted pyeloplasty, showing similar outcomes in short-term follow-up.^{28,32,33} While the earliest reports on robotic assisted pyeloplasty have involved adults; the application of robotic techniques to the treatment of children with UPJ obstruction has been reported as well. Peters et al described their initial experience, reporting a 'satisfactory' outcome in 94% of patients, and a recent study comparing robotic pyeloplasty with an open cohort demonstrated decreased hospital stay and narcotic use in the former.^{30,34}

In the performance of the procedure, our group utilizes a transperitoneal approach using three robotic arms and a 12 mm assistant port (Figure 9.9). The patient is placed in a modified decubitus position, and initial access obtained via an open technique and placement of a Hasson trocar. After placement of the trocars and docking of the robot, the colon is reflected, exposing the kidney and renal pelvis. The ureter is identified and

traced to the UPJ, which is usually readily apparent with hydronephrosis. We have found that leaving the patient unstented prior to starting the procedure allows the pelvis to remain dilated, and facilitates identification of the relevant anatomy, including crossing vessels. In cases where excessive hydronephrosis hinders dissection of the UPJ, the renal pelvis may be aspirated by the assistant, decompressing the system to a more manageable size. Using robotic cautery shears or Potts scissors, the renal pelvis is incised at its most dependent position and the UPJ dismembered. If the renal pelvis is excessively large, the pelvis is tapered. The ureter is then spatulated laterally. The UPJ is then reconstructed anterior to any crossing vessels. An interrupted 3-0 Monocryl stitch is placed at the apex of the spatulated ureter, and sewn to the dependent portion of the transected renal pelvis. We then perform a running anastomosis of the posterior wall. Next, the bedside assistant feeds a JJ stent through the laparoscopic suction tool over a guide wire, which is directed down the ureter by the console surgeon. After removal of the wire, the proximal end of the stent is fed into the renal pelvis. To confirm that the distal end of the stent is in the bladder, saline can be injected into the Foley catheter until reflux is seen from the proximal end of the stent. The anterior layer of the anastomosis is then completed with a third 3-0 Monocryl suture. The anastomosis is then retroperitonealized by replacing the reflected colon over the kidney, which is usually held in place by several interrupted sutures placed through the peritoneum. A drain is then placed through the most dependent robotic trocar site. We typically remove the drain just prior to discharge if the output is minimal following removal of the Foley catheter on postoperative day 1. Patients typically are discharged by 23 hours, and the stent is removed in the office at 2 weeks.

With an increasing number of institutions and surgeons becoming at ease with robotic technology, the experience with robotic assisted pyeloplasty will accumulate. At the present time, limited data suggest that at least in the short term, the procedure appears to be technically feasible and safe, with outcomes comparable with those seen with standard laparoscopic approaches. However, no long-term data are yet available, and it remains to be seen whether or not robotic assisted pyeloplasty will be able to match the success rates of open pyeloplasty, which remains (for now) the gold standard for the treatment of UPJ obstruction.

ROBOTIC CYSTECTOMY AND PARTIAL CYSTECTOMY

Radical cystectomy is a formidable procedure that remains one of the most technically demanding procedures

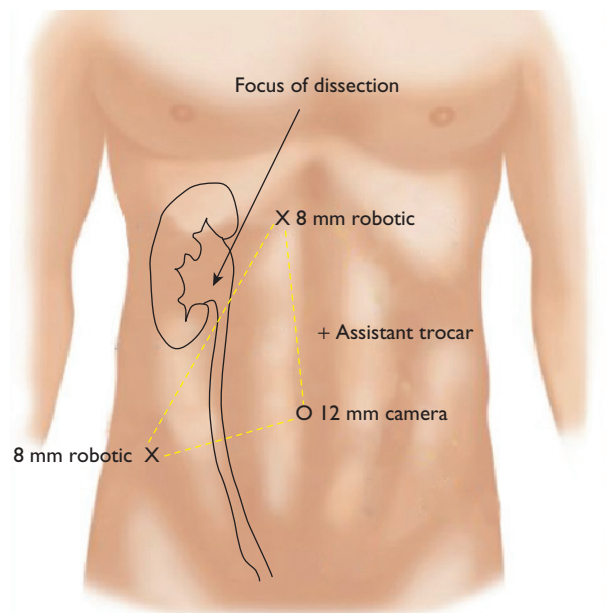


Figure 9.9 Trocar placement for right-sided robotic assisted pyeloplasty.

performed by urologists. Even after decades of experience and refinement of the open approach, complication rates remain near 30% in expert hands.³⁵ The morbidity of the radical cystectomy has stimulated an intense interest in developing less invasive, and theoretically less toxic, surgical treatments that maintain the efficacy of the open approach. With the advent of laparoscopy and its application to such urologic procedures as the pelvic lymph node dissection, nephrectomy, and radical prostatectomy, early attempts at cystectomy were undertaken. Parra et al first described laparoscopic cystectomy in 1992, when they removed a bladder in a patient with recurrent pyocystis who had previously undergone urinary diversion.³⁶ Since that time, multiple series of laparoscopic cystectomy for both malignant and non-malignant applications have been reported, with decreased blood loss, reduced hospital stay, and improved cosmesis touted as potential benefits for the laparoscopic approach. Techniques for nerve sparing³⁷ and approaches in the female with sparing of the uterus have been described.³⁸ However, the procedure remains a technically demanding one, and even in the hands of expert laparoscopists carries risk for significant complications. Additionally, the long-term oncologic efficacy of the procedure remains undetermined, as even the largest series have relatively few patients with follow-up over a few years.³⁹⁻⁴¹

The emergence of surgical robotics, in particular the application of the da Vinci surgical system to radical prostatectomy has re-invigorated the search for a better cystectomy. In particular, laparoscopic cystectomy

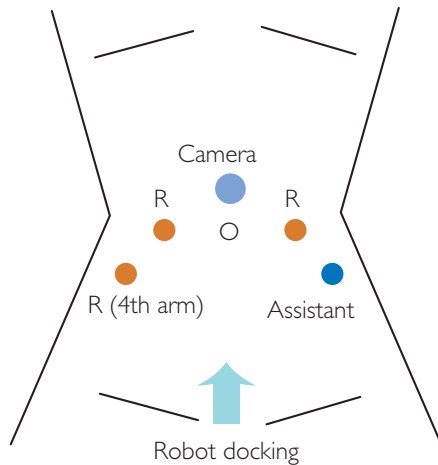


Figure 9.10 Trocar placement for robotic assisted laparoscopic cystectomy.

seems particularly suited to a robotic approach, as it is technically demanding, includes often difficult maneuvers near major vascular structures, and already has a procedural framework upon which to build in the form of the robotic radical prostatectomy.

The first reported use of robotic assistance for radical cystectomy was from Menon et al in 2003.⁴² They completed radical cystectomy in 14 men and three women using a three-step technique. Urinary diversion with either ileal conduit or a neobladder was completed extracorporeally. This report established the feasibility and safety of the procedure, and showed that a nerve sparing approach could be undertaken while maintaining negative margins and minimizing the size of the incision needed for extraction. Interestingly, the authors seemed to imply that the advantages of robotic assistance would not extend to the performance of an intracorporeally constructed urinary diversion, as all diversions were created extracorporeally using open techniques.

Since this initial description, several other series have appeared in the literature. Recently, Rhee et al reported on a series of seven patients who underwent a robotic cystectomy using the techniques reported by Menon et al, and compared outcomes with those of 23 patients who underwent open radical cystectomy over the same time span. The robotic cases had less blood loss (479 ml vs. 1109 ml, $p=0.002$), but there were no differences in transfusion rates. The robotic procedure was also associated with longer operative time, but did not result in a shorter hospital stay. Surgical margins were negative in all patients from both groups. The authors concluded that the robotic approach resulted in less blood loss, although the long-term oncologic efficacy and economic feasibility of this approach remain to be determined.⁴³

At the authors' institution, robotic radical cystectomy is now routinely performed in patients with muscle invasive bladder cancer. We use a four-arm da Vinci unit, with a five-port configuration similar to that used for radical prostatectomy, with a 12 mm assistant port placed on the patient's left lower quadrant (Figure 9.10). The patient is positioned in a low lithotomy position in steep Trendelenburg, and the robot docked from below. We use monopolar cautery shears, grasping forceps, and the Gyrus Plasmakinetic™ bipolar forceps as the robotic instruments of choice for the initial dissection, including performance of a pelvic lymph node dissection in all patients. After completion of the node dissection, the ureters are divided at the level of entry into the bladder, and distal margins sent for frozen-section analysis. The bladder and prostate pedicles are then isolated and divided, and the prostate divided from its urethral attachments after controlling the dorsal venous complex with a suture ligature. Before removal of the specimen, the left ureter is tunneled under the root of the mesentery, which we have found helps to facilitate ex vivo urinary reconstruction. The robot is then undocked, and the specimen removed through a minilaparotomy incision. Urinary diversion is then completed ex vivo as reported with the aforementioned authors, as we feel this increases the speed of completing the diversion while still maintaining the minimally invasive nature of the operation. In cases where a neobladder is performed, the robot can be re-docked, and the urethral–neobladder anastomosis performed robotically.

In the authors' initial series of nine consecutive patients, all were completed successfully, with one early open conversion for bleeding. Median total operative time was 379 minutes, with a median console time of 196 minutes. Median EBL was 500, with three patients requiring transfusions. Median length of hospital stay was 120 hours, with a time to regular diet of 96 hours. All patients save one with T4 disease had negative margins, and overall survival at 6 months was 78%.⁴⁰

Robotic assisted radical cystectomy remains a novel technique, being performed at select centers with extensive laparoscopic and robotic experience. While the long-term oncologic efficacy and widespread applicability of the technique remain to be determined, in early series it appears to hold promise as a means to reduce the morbidity and improve the lives of patients suffering from bladder cancer.

Paralleling the experience with radical cystectomy, innovations in robotic techniques have been applied to partial cystectomy, namely for the extirpation of urachal lesions including adenocarcinoma. Madeb et al described a technique for robotic excision of the urachal tract

abnormalities that were performed in five patients, four of whom had partial cystectomies. This small series demonstrated the feasibility of the technique, with promising perioperative outcomes (no bladder leaks) and short-term oncologic outcomes (no recurrences at a median follow-up of 8 months).⁴⁴ This procedure seems especially well suited for robotic assistance, as it takes advantage of the robot's unique ability to perform intracorporeal suturing and reconstructive techniques using three-dimensional visualization.

ROBOTIC ASSISTED RETROPERITONEAL LYMPH NODE DISSECTION

Retroperitoneal lymph node dissection (RPLND) remains an effective therapeutic option for patients suffering from testicular cancer. While the open surgical approach is considered by many to be the 'gold standard', enjoying extensive published evidence demonstrating efficacy, it is a highly morbid procedure, requiring a large incision and carries the risk of bowel, vascular, and neurologic complications. In addition, even in the best of hands, patients can expect a lengthy hospital stay and recovery, with nearly all patients experiencing a postoperative ileus. In an attempt to reduce the morbidity of the open approach, numerous investigators have applied laparoscopic techniques to the RPLND, which was first reported by Rukstalis in 1992.⁴⁵ Despite the reported reductions in blood loss, hospital stay, and patient morbidity, the technique remains challenging even in the most experienced hands, with the potential for serious complications. Furthermore, its efficacy has been questioned, as most patients in the laparoscopic group were given adjuvant chemotherapy.⁴⁶

In an effort to enhance the laparoscopic approach to RPLND, the authors have applied surgical robotics to the technique. The technical advantages of the robot seem perfectly suited to overcoming the difficulties inherent in performing complex maneuvers near major vascular structures. The authors reported the first use of the da Vinci system in this manner, and have since used it successfully with several more patients, with no relapses in short-term follow-up. We have found that the robot greatly facilitates the surgeon's ability to do a more thorough node dissection, making the procedure more accurate as well as safer. The morbidity associated with the technique is greatly reduced when compared with the open approach, as most patients have no ileus and are discharged from the hospital 1–2 days after surgery. The long-term efficacy of this promising application of robotic technology awaits further study.

PELVIC FLOOR RECONSTRUCTION AND INCONTINENCE SURGERY

Stress urinary incontinence

While many surgical options are available for the treatment of stress urinary incontinence in women, a large body of literature demonstrates the efficacy and durability of the open Burch colposuspension. Paralleling other urologic surgeries, laparoscopic techniques have been applied to this tried and true technique with the goal of reducing morbidity and potentially improving efficacy. Several studies have shown laparoscopic Burch colposuspension to be well tolerated and efficacious in the short term, with reduced blood loss, less pain, and quicker return to normal activity.^{47,48} Surgical robotics, as with other procedures, has been applied to the laparoscopic Burch colposuspension. The first description in 1995 by Partin et al demonstrated the feasibility of this procedure using rudimentary robotic assistance, with a two-arm set-up to hold the laparoscope and provide retraction assistance, but to date no published data exist describing the technique with the new da Vinci surgical system.²³ At the author's institution, robotic Burch colposuspension has been performed in seven patients, with three having undergone prior sling procedures that failed. Median total operative time was 155 minutes, with a console time of 81 minutes. Median EBL was 20 ml, and all patients were discharged on the first postoperative day. In follow-up, all but one patient is dry, with improvement in urinary symptoms by validated questionnaires. This technique seems particularly well suited to those patients with severe atrophic vaginitis or other reasons to avoid vaginal surgery, and affords the opportunity to perform reconstructive procedures such as sacrocolpopexy in a single setting. Finally, there have been reports of sexual dysfunction following placement of synthetic mesh slings, with dyspareunia reported in up to 14% of patients.^{49,50} The robotic Burch, as with the open technique may lead to better sexual function for both the patient and her partner by avoiding the introduction of foreign material close to the vaginal lining.

Pelvic organ prolapse

Laparoscopic pelvic organ prolapse repair has gained increasing attention, with several reports now demonstrating efficacy of the laparoscopic sacral colpopexy.⁵¹ However, the potential advantages of reduced patient morbidity compared with open approaches are tempered by the inherent difficulties in complex laparoscopic techniques and the long operative times often necessary to

complete reconstructions laparoscopically. This seems an ideal application for the robot, and several authors have described this adaptation. In the largest series to date, Elliot et al described a four-port technique using a three-arm da Vinci system. Interestingly, the robot was docked after vaginal mobilization and sacral dissection where completed laparoscopically. A Y-shaped Prolene mesh graft was then used to secure the vaginal apex to the sacral promontory, using the suturing ability of the robot to increase the speed and accuracy of this step. Following this, a standard Halban culdoplasty with placation of the ureterosacral ligaments was also performed. A total of 20 patients with severe prolapse underwent the procedure, with a mean total operative time of 3.2 hours. Eight patients underwent concomitant incontinence procedures, and all but one was discharged post-operative day 1. At mean follow-up of 5 months, there was only one recurrence (grade 3 rectocele). Complications included port-site infection in two patients, and persistent vaginal bleeding related to the anti-incontinence portion of the procedure. Patient satisfaction was purported to be 100%.⁵² In a smaller study of five patients using similar techniques, Di Marco et al reported no recurrences at a mean follow-up of 4 months, with no significant complications.⁵³ The ability of this approach to mimic open techniques and potentially match durability and improve morbidity for the patient make it a strong challenger to traditional open techniques, and it may become the standard of care in the future.

SUMMARY

Robotic surgical techniques continue to be actively embraced by the urologic community. A review of this type serves to elucidate the wide breadth of procedures that can benefit from robotic assistance. In some procedures such as radical prostatectomy, there has been rapid progression in both utilization of the robotic platform and evolution of technique. In other procedures such as cystectomy and retroperitoneal lymph node dissection, robotic applications are in their infancy. The key will be determining which procedures exploit the obvious strengths of the robot such as improved visualization and precise dissection and thus provide an advantage over open or conventional laparoscopic techniques.

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10 Reconstructive surgery after renal trauma

Jill C Buckley and Jack W McAninch

INDICATIONS FOR SURGERY

The incidence of renal injury in all trauma patients is low at 2–3%.¹ Renal exploration rates vary between blunt and penetrating trauma and are reported to be between 0.5–2% for blunt injuries and 50–100% for penetrating injuries.² Historically, all penetrating trauma underwent operative exploration but with improved solid organ injury staging via computed tomography (CT), the addition of minimally invasive interventional radiology techniques, and improved intensive care monitoring more non-operative management is being undertaken for penetrating injuries.^{3–6}

At presentation, the acute resuscitation of the patient is essential, stabilizing the airway, breathing, and circulation. Renal injuries may present with abdominal or flank pain, ecchymosis, or tenderness. They can be associated with rib or spinous process fractures. Hematuria can be gross, microscopic, or absent and does not necessarily correlate with the degree of injury.⁷ Standard laboratory values are obtained with the initial and trend of serial hematocrits used as critical components in decision making analysis. Unstable patients require immediate exploratory laparotomy with an intraoperative single shot intravenous pyelogram (IVP) to document a functioning contralateral kidney and operative staging of the injured renal unit.⁸ Hemodynamically stable patients undergo abdominal and pelvic CT imaging to detect and determine the extent of injuries.^{9,10}

CT staging of renal injuries along with clinical presentation, mechanism of injury, and hemodynamic stability has allowed selective management of renal injuries. Grade I–III injuries are managed non-operatively with excellent renal preservation and minimal risk of future morbidity.^{10,11} More severe renal injuries (grades IV–V) often occur with serious associated injuries that require operative exploration. Renal exploration and reconstruction is performed concurrently reducing the risk of late complications and a prolonged recovery phase.

Absolute indications for renal exploration are in patients who demonstrate active bleeding by hemodynamic instability, or an expanding or pulsatile hematoma. Relative indications include ureteropelvic junction injury,

Table 10.1 Indications for renal exploration

<i>Absolute</i>
Expanding renal hematoma
Pulsatile hematoma
<i>Relative</i>
Urinary extravasation
Non-viable tissue
Arterial injury
Incomplete staging

significant devitalized renal tissue with active urinary extravasation, segmental arterial extravasation, incomplete renal staging, and limited intensive care facilities (Table 10.1). Each relative indication needs to be considered on an individual patient basis along with the overall clinical assessment. A stable patient with a severe renal injury being explored for other abdominal injuries should undergo concomitant renal exploration with early vascular control and repair.

Severe renal vascular injuries require immediate operative exploration to prevent life-threatening hemorrhage. Damage control nephrectomy is required in the critically ill patient with multiple associated injuries and a high mortality risk.^{10,12,13} Although uncommon, isolated venous injuries can be successfully repaired but should only be pursued in a hemodynamically stable patient. Main renal artery injuries that require extensive reconstruction should only be performed in patients with a solitary kidney or bilateral severe renal injuries as renal salvage is poor.^{13,14}

Figure 10.1 shows the surgical approach to renal exploration. A midline transabdominal incision from the xyphoid to the pubic symphysis provides maximum exposure for complete abdominal exploration to detect associated organ injury. Immediate bleeding should be controlled with laparotomy packs and surgical repair.

Figure 10.2A shows access to the renal hilum. The midline transabdominal approach provides the optimal exposure of the great vessels and facilitates isolation of the respective renal vessels. The transverse colon is placed onto the chest over a moist laparotomy pack. The small bowel is retracted superiorly and to the right allowing access to the retroperitoneum. The inferior mesenteric vein (IMV) can then be identified in the

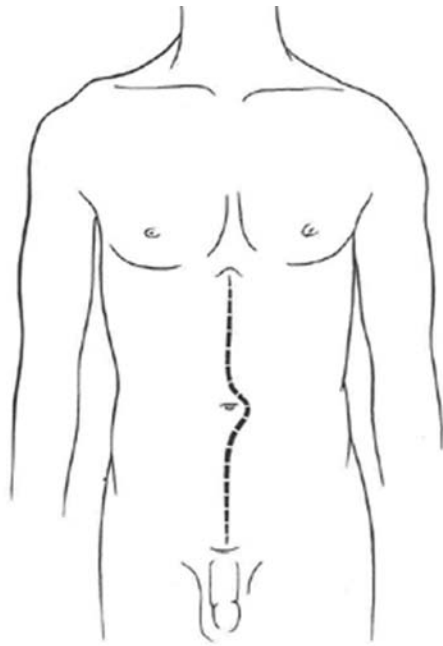


Figure 10.1 Surgical approach to renal exploration.

mesentery of the left colon and used as a landmark to identify the aorta. This is especially important when a large retroperitoneal hematoma prevents direct visualization and/or palpation of the aorta. An incision should be made just medial to the IMV cephalad to the inferior mesenteric artery and extended up to the ligament of Treitz. The anterior surface of the aorta is dissected superiorly.

Figure 10.2B shows isolation of the renal vessels.¹⁵ The first major vessel encountered will be the left renal vein crossing anterior to the aorta. This is a key anatomic landmark. The left renal artery is usually located posterior and slightly superior to the left renal vein.

Access to the right renal hilum is easily achieved through the same incision and approach. The right renal artery can be identified in the intra-aortacaval space by elevating the left renal vein and dissecting on the medial aspect of the aorta. The right renal vein can be found on the lateral aspect of the vena cava at about the same level as the left renal vein. Mobilization of the secondary portion of the duodenum may be required

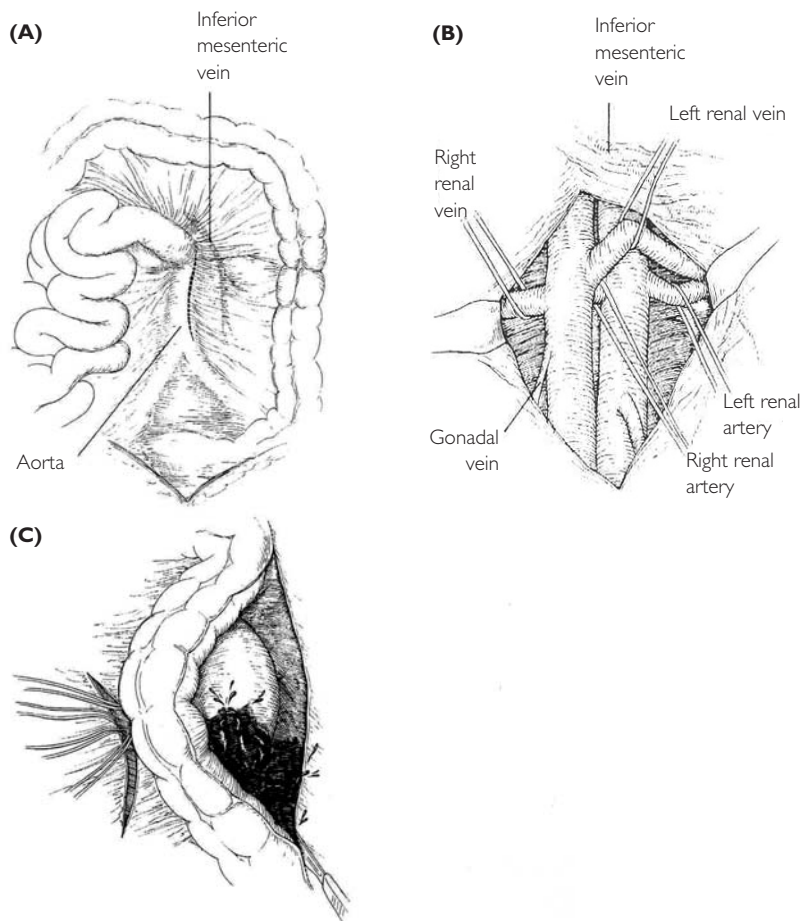


Figure 10.2 (A) Access to the renal hilum. (B) Isolation of the renal vessels. (C) Kidney exposure.

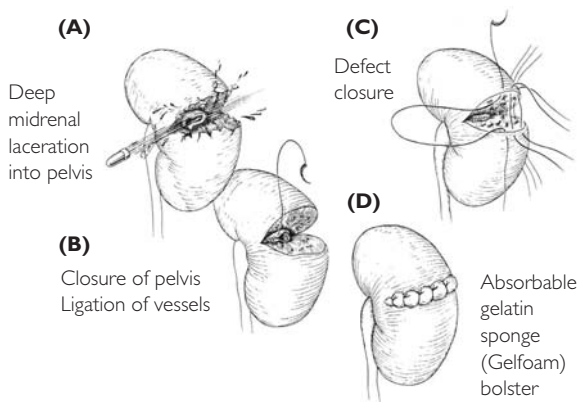


Figure 10.3 Renorrhaphy. (A) Deep midrenal laceration into pelvis. Basic reconstructive principles of renorrhaphy include (B) closure of pelvis and ligation of vessels, (C) defect closure, and (D) placement of Gelfoam® bolsters.

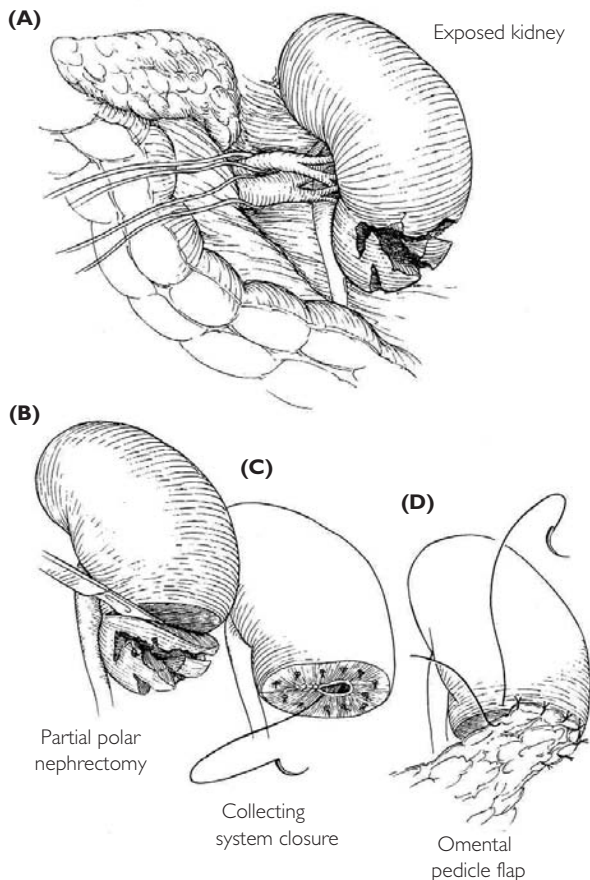


Figure 10.4 Polar partial nephrectomy. (A) Exposed kidney. (B) Partial polar nephrectomy. (C) Collecting system closure. (D) Omental pedicle flap.

to identify the right renal vein. Vessel loops are placed around the artery and vein of the injured kidney in anticipation of opening the retroperitoneal hematoma.

Unless severe bleeding is encountered, the vessels are not clamped avoiding warm ischemia when possible.

Figure 10.2C shows kidney exposure. The colon is mobilized medially by incising the retroperitoneum lateral to the colon. Gerota's fascia is opened vertically and the hematoma around the kidney is evacuated. The kidney is completely mobilized and delivered through Gerota's fascia. Complete exposure of the kidney is required to determine the extent of the injury and to avoid a missed injury.

Major middle pole injuries or smaller polar injuries can be reconstructed by renorrhaphy (Figure 10.3). Basic reconstructive principles must be instituted which include sharp debridement of non-viable tissue, individual suture ligation of bleeding parenchymal vessels and watertight closure of the collecting system, placement of hemostatic and/or tissue sealants followed by Gelfoam® bolsters, and capsular closure using an absorbable 3.0 suture in an interrupted fashion.

Figure 10.4 shows polar partial nephrectomy. Once the kidney is completely exposed the extent of the injury can be determined (Figure 10.4A). A large devitalized area is best managed by a partial polar nephrectomy sharply removing all the non-viable tissue (Figure 10.4B). As in the renorrhaphy reconstruction, the collecting system is closed in a watertight fashion using a continuous absorbable suture and the bleeding vessels are individually suture ligated. A hemostatic agent is applied directly to the defect site. If renal capsule is available, it is closed over the defect (Figure 10.4C). Alternatively, an omental pedicle flap can be utilized to cover the parenchymal defect by placing several interrupted absorbable sutures to the edge of the remaining renal capsule (Figure 10.4D). Omentum has excellent absorbant properties and is beneficial to the wound healing process. If omentum is unavailable or difficult to obtain an absorbable polyglactin (Vicryl) mesh can be used in a similar fashion providing coverage and compression of a large defect. The mesh is trimmed to the shape of the defect and secured to the renal capsule in a similar fashion using interrupted absorbable suture. Absorption is achieved through hydrolysis over a period of 55–70 days with minimal tissue reaction.

The use of hemostatic agents and tissue sealants has become commonplace in all types of renal reconstruction. Fibrin glue, gelatin matrix/tissue sealants, cyanoacrylate, bioglues, and polyethylene glycol hydrogels are some of the agents available. Each has unique properties that assist in hemostasis either mechanically or by augmenting the coagulation cascade, and/or tissue approximation using sealants that bind to and close defects.

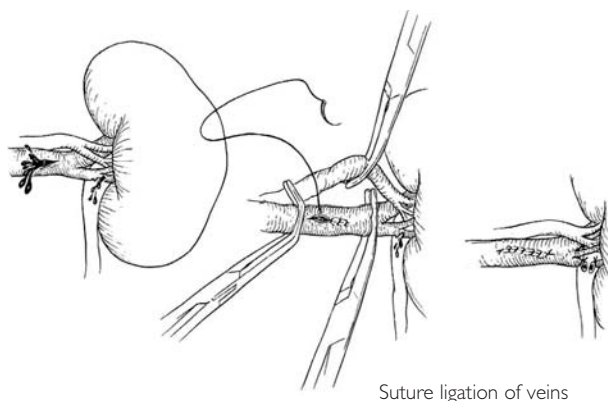


Figure 10.5 Repair of vascular injury.

Most renal losses are the result of vascular injuries (Figure 10.5). Complex vascular reconstruction is not recommended in the traumatic setting unless a solitary kidney is present or bilateral severe renal injuries occur.¹³ Partial main renal vein or arterial injuries can be primarily repaired after proximal and distal control have been obtained. A continuous 4.0 prolene suture is used to complete the repair. Segmental venous injuries can be safely suture ligated without ischemic damage to the kidney because of sufficient collateral circulation. Suture ligation of segmental arterial injuries will result in tissue ischemia as these represent end organ vessels.

DRAINS AND URETERAL STENTS

A flank drain in the form of a ½ inch penrose or a close passive suction drain is placed at the time of surgery if there is concern of a collecting system injury. A suction drain is avoided as it may potentiate a urinary fistula. In the absence of a ureteral injury, a ureteral stent is not placed at the original exploration and repair.

POSTOPERATIVE CARE

Severe renal injuries requiring exploration and reconstruction often occur in the setting of other severe injuries requiring intensive care monitoring. A postoperative hematocrit is obtained and the patient is placed on bedrest until the hematuria clears (often within 24 hours). Flank drains in the form of a penrose or closed passive suction are checked for creatinine and compared to serum to assess if a urinary leak is present. The drain should be removed within 48 hours presuming no leak is demonstrated to prevent infection of the retroperitoneum. If a urinary leak is identified a ureteral stent is

placed to hasten closure of the collecting system.¹⁶ Persistent hematuria may indicate development of an arterial venous malformation or pseudo-aneurysm requiring angioembolization.¹⁷ Patients are advised to avoid all strenuous activity for a 2 month period and are informed of the delayed risk of bleeding. A radionuclear renal scan and/or CT scan are obtained in the acute 3 month perioperative period to document postoperative function. These patients should be monitored regularly to detect hypertension.

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Open partial nephrectomy for kidney cancer

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INTRODUCTION

Renal cortical tumors account for about 3% of all solid neoplasms, with an incidence similar to that of all forms of leukemia combined.¹ The incidence of renal cell carcinoma (RCC) has risen by 2.3–4.3% each year during the past three decades, resulting in an estimated 38 890 new diagnoses and 12 840 deaths in 2006 in the US alone.^{1,2} As about one-third of patients diagnosed with RCC die of metastatic disease progression, RCC is the most lethal of the major genitourinary malignancies.¹ RCC most commonly presents as a unilateral, sporadic tumor, but multifocal sporadic tumors can be present in between 3 and 25% of patients,^{3–5} and an additional 1–2% of RCC can be attributed to known familial syndromes, such as von Hippel-Lindau (VHL) disease.⁶

Wells first described the technique of partial nephrectomy for excision of a renal tumor in 1884, and Czerny was the first to treat a renal malignancy using partial nephrectomy in 1897. Excessive postoperative morbidity limited its application until the 1950s, when Vermooten suggested that encapsulated, peripheral renal neoplasms could be removed with only a margin of normal parenchyma around the tumor. Robson et al challenged the oncologic safety of this approach by demonstrating in 1969 that early ligation of the renal vasculature, removal of the perinephric fat, and excision of all regional lymph nodes reduced the risk of hematologic spread.⁷ Robson's radical nephrectomy (RN), which involved excision of the affected kidney outside of its investing (Gerota's) fascia, along with the perinephric fat and ipsilateral adrenal gland, was standard treatment for RCC for more than 50 years. RN is still the best treatment for larger tumors, which are more likely to invade the perinephric fat, adrenal gland, or other neighboring organs, and is the standard against which all other treatments for RCC must be judged.

Surgical resection remains the cornerstone of treatment for RCC. Nephrectomy is curative for the majority of patients with localized RCC and some patients with advanced RCC benefit from nephrectomy prior to systemic therapy. RCC is refractory to standard chemotherapeutic agents, and immunotherapy results

in responses in between 10 and 15% of patients, with rare individuals having a durable cure.⁸ Several new molecularly targeted agents have shown promise in clinical trials, and two of these have recently been approved by the Food and Drug Administration of the US for the treatment of advanced RCC.⁹

Although RCC used to be referred to as the 'internist's' tumor, it may now be more appropriate to refer to it as the 'radiologist's' tumor, as more than 60% of renal tumors are detected incidentally on abdominal imaging obtained for various reasons. The small renal mass is therefore becoming an increasingly common clinical scenario, with a wide range of options for management. Incidentally detected tumors are often small, unlikely to metastasize, and amenable to treatment with nephron-sparing surgery (NSS).^{10,11} Recent findings suggest that NSS is greatly underutilized in the US, as only 9.6% of patients with surgically treated renal tumors in a large nationwide hospital database underwent partial nephrectomy.¹²

CURRENT INDICATIONS FOR NEPHRON-SPARING SURGERY

The increasing detection of small renal masses, advances in computed tomography (CT) and magnetic resonance imaging (MRI) of the kidney, improved surgical technique and methods to prevent ischemic renal injury, better postoperative management including renal replacement therapy, and long-term cancer-free survival data, have stimulated the expanded usage of NSS. Time has shown that open partial nephrectomy (OPN) can be performed safely, with low morbidity and high patient satisfaction, and provides outstanding oncologic and renal functional outcomes at 10 years and longer.^{13–16}

Absolute indications for NSS include conditions that would render the patient dialysis dependent upon complete resection of tumor-bearing kidneys, i.e. bilateral tumors or tumor in a solitary functioning kidney. Relative indications for NSS include the presence of any condition that poses a current or future risk to renal function, such as calculus disease, renal artery stenosis, chronic pyelonephritis, ureteral reflux, or

systemic diseases such as diabetes and hypertension. Elective NSS is defined as treatment of a single, small (≤ 4 cm), clinically localized RCC in a patient with a normal contralateral kidney. Several reports have demonstrated that NSS provides equivalent oncologic and superior renal functional results to radical nephrectomy for these patients.^{17–20}

The results of NSS have been reported to be less satisfactory in patients with larger (>4 cm) or multiple localized RCCs, and radical nephrectomy remains the treatment of choice in such cases when the opposite kidney is normal.²¹ However, recent data have suggested that NSS can be performed safely for a single tumor of up to 7 cm, and ‘elective’ NSS may be a reasonable option for any patient with a clinical T1 renal tumor.^{22–24} In one study, cancer-specific mortality occurred in 6.2% and 9.0% of patients with pT1b tumors treated with OPN ($n = 65$) or RN ($n = 576$).²³ In two other reports, Kaplan–Meier estimates of distant metastasis-free survival were 92–94% and 83% following OPN ($n = 91$ and $n = 33$) or RN ($n = 841$ and $n = 66$) at 5 years, respectively.^{22,25} In a fourth report, only four of 69 (5.8%) patients undergoing OPN for a cT1b tumor developed distant metastases over a median follow-up interval of 5.8 years.²⁴ In each of these studies, a survival advantage was observed with OPN; the most likely explanation for these findings is the bias inherent in selecting tumors amenable to NSS.²⁶ Expanding the indications for elective NSS to include 4–7 cm tumors therefore remains controversial due to the increased likelihood of micrometastases, multicentricity, and perioperative morbidity in patients with larger tumors.²⁶

EVALUATION PRIOR TO NEPHRON-SPARING SURGERY

Complete evaluation of patients with suspected RCC must include a complete history and physical examination, urinalysis or urine dipstick to screen for hematuria and proteinuria, and laboratory evaluation, including complete blood count, complete metabolic panel, and coagulation factors. Radiographic evaluation, including chest X-ray and abdominal CT or MR imaging, can rule out locally advanced or metastatic disease and aid in surgical planning. Three-dimensional reconstruction of CT or MR images is routinely performed by radiologists at our Urological Institute prior to partial nephrectomy in order to accurately delineate the vascular anatomy and the relationship of the tumor to normal parenchyma. This 2–4 minute videotape is reviewed

immediately prior to surgery, so the surgeon can anticipate the subtleties of the anatomy.

OPEN PARTIAL NEPHRECTOMY

Operative technique

It is usually possible to perform open partial nephrectomy for malignancy in situ by using an operative approach that optimizes exposure of the kidney and by combining meticulous surgical technique with an understanding of the renal vascular anatomy in relation to the tumor.

Generally an extraperitoneal flank incision through the 11th and 12th ribs is preferred. Occasionally a thoracoabdominal incision is utilized for very large tumors involving the upper portion of the kidney. These incisions allow the surgeon to operate on the mobilized kidney almost at skin level and provide excellent exposure of the peripheral renal vessels. With an anterior subcostal transperitoneal incision, the kidney is invariably located in the depth of the wound, and the surgical exposure is not as good.

The kidney is mobilized within Gerota’s fascia, leaving the perirenal fat around the tumor undisturbed. The surface of the kidney is then evaluated for small abnormalities that may occasionally be missed by non-invasive imaging. In most cases, and in particular with large or intrarenal tumors, temporary occlusion of the renal artery is useful for decreasing bleeding and renal tissue turgor. For central tumors the renal vein is also temporarily occluded. To prevent renal ischemic injury, the patient is briskly hydrated and mannitol is given intravenously 5–10 minutes before arterial occlusion to decrease intracellular swelling. It is re-administered after the vascular clamp is removed to promote a brisk diuresis. If the anticipated time of arterial occlusion is greater than 30 minutes, in situ renal hypothermia is used to minimize ischemic injury to the kidney. Surgical hypothermia is established immediately after renal artery clamping and maintained for 10 minutes to decrease core temperature to 15–20°C prior to initiating tumor resection. Surface cooling of the kidney allows up to 3 hours of safe ischemia without permanent injury.

An assortment of surgical techniques is available for performing partial nephrectomy in patients with renal tumors. These include polar (apical and basilar) segmental nephrectomy, wedge resection, and transverse resection. Extracorporeal NSS with autotransplantation is required only in rare cases with exceptionally large and

anatomically challenging tumors. Hemostasis is accomplished by ligation of arterial and venous bleeders during and after tumor excision with fine absorbable suture and coagulation with electrocautery, laser, or argon beam devices. Closure of the renal defect with adjacent fat, fascia, peritoneum, or Oxygel and watertight closure of the collecting system with fine absorbable suture are critical in prevention of urinary fistula development.

Whichever technique is used, the tumor is removed with a thin margin of adjacent normal appearing renal parenchyma. While obtaining a negative surgical margin around the tumor is imperative, the width of this parenchymal margin does not affect the likelihood of recurrence.²⁷ Although some renal tumors are surrounded by a distinct pseudocapsule of fibrous tissue, and simple enucleation has been used in such cases to achieve tumor removal, most recent studies have linked enucleation with a higher risk of leaving residual malignancy in the kidney. Histopathological studies have demonstrated frequent microscopic tumor penetration of the pseudocapsule that surrounds the neoplasm and thus it is not always possible to be assured of complete tumor encapsulation. Every attempt should be made to prevent local tumor recurrence and, therefore, a surrounding margin of normal parenchyma should be removed with the tumor whenever possible. Enucleation is currently used only in patients with von Hippel-Lindau disease who have multiple low-stage encapsulated tumors involving both kidneys.

Although intraoperative ultrasonography is not superior to CT in identifying multifocal tumors, it can determine tumor extent and achieve accurate tumor localization, particularly for intrarenal lesions that are not visible or palpable from the external surface of the kidney. Furthermore, determination of venous extension and associated cysts may also be aided by intraoperative sonography. Intraoperative ultrasound is therefore a particularly useful tool in renal exploration in patients with hereditary forms of RCC or those undergoing re-operation, who are at a high risk for having multiple intrarenal lesions that may otherwise go unrecognized.

When NSS is performed, after excision of all gross tumor, absence of malignancy in the remaining portion of the kidney should be verified intraoperatively by frozen-section examinations of biopsy specimens obtained at random from the renal margin of excision. It is unusual for such biopsies to demonstrate residual tumor but, if they do, additional renal tissue must be excised.

The frequency of postoperative complications after NSS continues to decline as patient selection, operative techniques, perioperative care, and cumulative

surgical experience improve. In the past decade, most large series have shown a dramatic decrease in the complication rate following NSS. Operative mortality is rare and reported to be 1–2% in most studies. A number of technical complications specific to NSS have been described. Of these, urinary fistula is the most common with a reported incidence of 1.4–17.4%. Diagnosis is made when persistent drainage demonstrates elevated creatinine (drainage fluid-to-serum ratio greater than 2). Almost all fistulas may be managed conservatively by observation, Foley catheter placement, and/or insertion of a ureteral stent. If a urinoma develops, percutaneous drainage may be necessary. Prolonged acute tubular necrosis (ATN) with or without acute renal failure is the second most common complication after NSS, with a frequency of occurrence between 0.7 and 7.3%. The primary etiology of ATN is ischemic renal injury and a decreased renal mass, although other causes of acute tubular necrosis/acute renal failure must be considered, including pre- and postrenal causes. Operative maneuvers to prevent ATN include vigorous hydration and administration of mannitol to promote a brisk intraoperative diuresis. Other reported complications are postoperative hemorrhage, infection, or injury to adjacent viscera. Careful intraoperative attention to hemostasis and precise reconstruction of the remnant kidney are mandatory to avoid these complications. Patients with an increased risk of technical complications after NSS include those with imperative indications (functionally solitary kidney or bilateral lesions) and large or centrally located tumors.

Postoperative follow-up after NSS involves serum creatinine measurement and excretory urography at 4–6 weeks to document renal function and anatomy. Subsequent surveillance strategies (Table 11.1) follow stage specific guidelines²⁸ and are no more extensive or expensive than surveillance after radical nephrectomy for low stage pT1 or pT2 disease. The need for postoperative radiographic surveillance studies varies according to the initial pathologic tumor (pT) stage. Patients who undergo NSS for pT1 RCC do not require radiographic imaging postoperatively in view of the very low risk of recurrent malignancy. A yearly chest radiograph is recommended after NSS for pT2 or pT3 RCC because the lung is the most common site of postoperative metastasis in both groups. Abdominal or retroperitoneal tumor recurrence is uncommon in pT2 patients, particularly early after NSS, and these patients require only occasional follow-up abdominal CT scanning. Patients with pT3 RCC have a higher risk of developing local tumor recurrence, particularly during

Table 11.1 Recommended postoperative surveillance after nephron-sparing surgery for sporadic localized renal cell carcinoma

Pathologic tumor stage	History, examination, blood test*	Chest X-ray	Abdominal CT scan
T1	Yearly	—	—
T2	Yearly	Yearly	Every 2 years
T3	Yearly	Yearly	Every 7 months for 2 years, then every 2 years

* Medical history, physical examination, and measurement of serum calcium, alkaline phosphatase, liver function, and renal function.

the first 2 years after NSS, and they may benefit from more frequent follow-up abdominal CT scanning initially. Locally recurrent disease may be treated with repeat partial or complete nephrectomy depending on the clinical circumstances and the anatomy of the remnant kidney.

Clinical outcomes

Several groups have reported oncologic results following OPN for RCC at 5 or more years of follow-up.^{13–31} A total of 84 (6.3%) distant and 43 (3.2%) local recurrences were detected when considering only the 1336 patients in the largest series from each institution (Table 11.2). Oncologic outcomes for the subset of patients undergoing elective OPN are particularly outstanding, with cancer-specific survival rates at 10 years that range from 94.5% to 97%.^{14,16} Fergany et al provided data regarding 10-year outcomes in 107 patients who underwent OPN, many of whom had adverse clinical and pathologic features.¹⁴ Preoperative renal insufficiency was present in 39% of patients and NSS was imperative in 90%.¹⁴ Recurrence was more common in patients with systemic symptoms, larger tumors, and advanced pathologic tumor stage; cancer-specific survival for the entire cohort was 88% at 5 years and 73% at 10 years.¹⁴

Long-term renal functional outcomes are superior in patients undergoing OPN compared with radical nephrectomy. Lau et al reported that progression to renal insufficiency (defined as serum creatinine >2.0 mg/dl) at 10 years occurred in 22.4% of patients undergoing radical nephrectomy compared with 11.6% undergoing OPN.²⁰ In another study with mean follow-up of 33 months, 3.7% and 12.3% of patients developed renal insufficiency after OPN or RN, respectively.³² A prognostic algorithm based on age, gender, preoperative creatinine, and percent change in kidney volume was generated to predict the likelihood of renal insufficiency in these patients.³² Fergany et al reported the outcomes of 400 patients with a solitary renal remnant after OPN for tumor by a single

surgeon.¹⁵ At 10 years, overall survival was 77% and cancer-specific survival was 82% in these high-risk patients.¹⁵ Transient renal impairment occurred in 21%, but only 14 (3.5%) required postoperative dialysis.¹⁵ Only two of these patients required long-term dialysis, so early postoperative renal function was achieved in 99.5% of the patients.¹⁵ A total of 18 patients (4.5%) in the high-risk group progressed to renal failure at a mean of 3.6 years after OPN.¹⁵

LAPAROSCOPIC PARTIAL NEPHRECTOMY

Laparoscopic partial nephrectomy (LPN) attempts to duplicate the surgical principles of OPN, while offering the advantages of minimally invasive surgery, i.e. decreased postoperative pain, shorter convalescence, and superior cosmesis. Since LPN was first reported in 1993, more than 1500 patients have undergone LPN worldwide. At our institution, LPN typically involves transient en bloc renal vascular control, tumor excision with cold scissors, sutured reconstruction of the pelvicaliceal system, and sutured hemostatic suture repair of the renal parenchymal defect over Surgicel bolsters, performed through either a transperitoneal or retroperitoneal approach.³³ Currently available laparoscopic instrumentation has enabled more reliable control of the renal hilum, without which progress during LPN can be greatly impaired, and the introduction of tissue sealants has helped to decrease postoperative bleeding complications. Even with such advances, LPN is a technique that demands significant laparoscopic surgical experience and expertise. Techniques to enable cold ischemia during LPN have not been widely embraced; LPN therefore requires the surgeon to complete a significant amount of intracorporeal suturing within the time constraints of a safe interval of warm ischemia.

Selection of cases appropriate for LPN should be made carefully considering the individual tumor, patient, and surgeon. In each surgical series, LPN has initially been performed for small (<4 cm), peripheral

Table 11.2 Oncologic outcomes of open partial nephrectomy for renal cell carcinoma

Reference	Patients (n)	Mean tumor size (cm)	Survival		Recurrence	
			Overall cancer (%)	Specific (%)	Distant	Local
5-Year outcomes						
Steinbach et al, 1995 ²⁹	110	3.3	94	98	3 (1.7%)	3 (2.7%)
Lerner et al, 1996 ¹⁷	185	4.1	77	89	32 (17%)	11 (5.9%)
D'Armineto et al, 1997 ¹⁸	19	3.3	95	95	1 (5%)	0 (0%)
Barbalias et al, 1999 ³⁰	41	3.5	NA	98	1 (2.5%)	3 (7.3%)
Beldegrun et al, 1999 ³¹	146	3.6	86	93	8 (5.5%)	4 (2.7%)
Hafez et al, 1999 ²¹	485	2.7	81	92	28 (5.8%)	16 (3.2%)
Lee et al, 2000 ¹⁹	79	2.5	86	96	3 (3.8%)	0 (0%)
Lau et al, 2000 ²⁰	164	3.3	91	98	3 (1.8%)	5 (3.0%)
10-Year outcomes						
Herr, 1999 ¹³	70	3.0	93	97	2 (2.8%)	1 (1.4%)
Fergany et al, 2000 ¹⁴	107	4.7	45	73	30 (28%)	11 (10%)
Fergany et al, 2006 ¹⁵	400	4.2	77	83	69 (17%)	38 (9.5%)
Pahernik et al, 2006 ¹⁶	381	3.0	69	97	11 (2.9%)	9 (2.3%)
Summary (5-year data)	>1300	2.5–4.7	77–95	89–98	2–17%	0–10%

tumors. With increasing experience, the indications for LPN have been gradually expanded at certain centers to include patients with larger tumors. Nevertheless, increasing depth of invasion, increasing size, proximity to the renal hilum, posterior location, and anomalous renal anatomy make LPN more challenging.

COMPARISON OF OPEN VERSUS LAPAROSCOPIC PARTIAL NEPHRECTOMY

Data regarding 1049 partial nephrectomies performed at the Cleveland Clinic for single renal tumors 7 cm or less have recently been analyzed. Patients undergoing OPN ($n = 595$) comprised a higher-risk group when compared with the LPN group ($n = 454$). In the OPN and LPN groups, 18% and 1.8% had reduced performance status, 7.3% and 2.2% had serum creatinine more than 2 mg/dl, and 31% and 5.3% had tumor in a solitary functioning kidney, respectively. More tumors in the OPN group were more than 4 cm (39% versus 8.4%) and centrally located (53% versus 39%), and more proved to be malignant after excision (85% versus 74%). In both groups, a similar chance of intraoperative complications was observed (1.7% versus 1.8%) and blood loss was acceptable (mean 364 ml versus 262 ml). Mean warm ischemia time was 20.1 and 32.4 minutes during OPN and LPN, respectively. In multivariate analysis, this was expected to be 1.79 times longer for a patient undergoing LPN than for a similar patient undergoing OPN. In 2.2% of planned LPN, the patient underwent conversion to open surgery ($n = 6$) or radical nephrectomy ($n = 4$). In multivariable analysis, hospital stay following LPN was 0.52 times that of OPN (3.3 versus 6.1 days, respectively).

Postoperative complications occurred in 15.3% and 20.9% of patients with a 2.17 and 1.61 times greater chance of having a urologic or a non-urologic complication with LPN than OPN, respectively. In particular, the rate of postoperative hemorrhage was higher following LPN (2.0% versus 5.7%, odds ratio 3.66), while the rates of urine leak (2.9% versus 3.5%) and acute renal failure requiring dialysis (0.7%) were similar after OPN and LPN, respectively. More patients in the LPN group required a subsequent procedure compared with the OPN group (7.9% versus 3.2%, odds ratio 4.05). Three months after partial nephrectomy, 99.8% of renal units with OPN and 98.0% of renal units with LPN retained function. Three-year cancer-specific survival for patients with a single cT1N0M0 RCC exceeded 99% in both groups.

We conclude from these data that LPN can achieve early renal functional outcome comparable with that of OPN when applied to select patients with a single renal tumor 7 cm in size or smaller. LPN offers the advantages of shorter operative time, reduced hospital stay, and more rapid convalescence. However, LPN is associated with longer intraoperative ischemia time, more postoperative renal/urologic complications (particularly hemorrhage), and more frequent need for a subsequent procedure. Open partial nephrectomy remains the preferred approach for more complicated tumors such as those which are larger, hilar/intrarenal in location, and multicentric.

CONCLUSIONS

The incidence of small renal masses continues to rise worldwide. With the acceptance of elective partial nephrectomy for tumors less than 4 cm, and potentially for those less than 7 cm, the percentage of tumors that will be treated with partial nephrectomy will continue to grow. OPN has become the standard-of-care for tumors amenable to this approach, with established 10-year oncologic and renal functional outcomes. Minimally invasive techniques such as LPN are now being offered at several centers. Urologists must be knowledgeable about the indications, limitations, and outcomes with each approach, so that they can help patients to select the approach that best fits the individual tumor, patient, and surgeon.

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12 Laparoscopic partial nephrectomy

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INTRODUCTION

Renal cancer was predicted to be the seventh leading cause of cancer in men and the 12th leading cause of cancer in women in the US in 2006, accounting for about 3% of all cancers in American males, with a male: female ratio of about 1.7.¹ An estimated 38 890 new cases of renal cancer were expected in the US in 2006, with 12 840 (~33%) deaths.¹ Renal cell carcinoma (RCC) accounts for 85% of all renal cancers.

The routine evaluation of abdominal symptoms by ultrasound and computed tomography (CT) has led to a 2.3–4.3% increase in detection of RCC annually. Accordingly, the rate of incidental detection of small (<4 cm) renal tumors of low stage and low metastatic potential has increased by 60%.² Several minimally invasive nephron-sparing surgery (NSS) options are available for select patients with small renal tumors, including excisional (laparoscopic partial nephrectomy; LPN) and probe ablative procedures (cryoablation and radiofrequency ablation). Notably, LPN is a technically challenging procedure and requires advanced laparoscopic skills.³ Potential benefits of LPN are decreased morbidity, shorter hospitalization and convalescence, and preservation of renal function, while providing cancer control comparable with open partial nephrectomy (OPN).

The dissemination of minimally invasive techniques has made it possible for partial nephrectomy for most small renal tumors to be performed laparoscopically, with functional and oncologic outcomes comparable with OPN.³

FOUNDATIONS OF NEPHRON-SPARING SURGERY

The rationale for elective partial nephrectomy is based on two fundamental facts: first, patients at risk of developing kidney failure are likely to benefit from the functional advantage of NSS in the long term and, second, a significant fraction of small solitary renal masses presumed to be RCC are proven benign on final histopathology.^{4,5}

OPN laid the foundations of NSS, becoming the reference standard for the surgical treatment of the

small renal mass. OPN is associated with excellent oncologic and renal functional outcomes.⁶ However, it is also associated with the morbidity of the muscle-cutting flank incision that can be durable in up to 50% of patients.⁷ Moreover, a significant fraction of solid renal masses are benign. Of 2770 resections of solid renal tumors, 12.8% were found to be benign. When stratified by size, the proportion of benign masses was 25% for masses smaller than 3 cm, 30% for masses smaller than 2 cm, and 46% for masses smaller than 1 cm.⁵ Subjecting a patient with a one in three chance of having a benign tumor to a significantly morbid flank incision appears less than ideal. Consequently, such concerns have accelerated the momentous advances in minimally invasive NSS in the past 5 years. While 3- and 5-year oncologic outcomes are now available for LPN, probe-ablative techniques must still be considered developmental due to the lack of long-term oncologic data and the non-availability of histologic confirmation of definite cancer ablation.

EVOLUTION, INDICATIONS, AND CONTRAINDICATIONS

McDougall et al first reported LPN in the pig model in 1993.⁸ Clinical LPN was first reported transperitoneally in 1993 by Winfield et al⁹ and retroperitoneally in 1994 by Gill et al.¹⁰ LPN was initially limited to the treatment of small, peripheral, and exophytic tumors. Recent refinements in laparoscopic techniques and advances in technology as well as increasing experience have enabled surgeons to apply LPN gradually to more complex tumors such as tumors in the presence of concomitant renovascular disease, tumors in anomalous kidneys, multiple tumors, large tumors requiring heminephrectomy, cystic tumors, hilar tumors, tumor in a solitary kidney, central tumors abutting the renal sinus, and pT2 tumors or higher.^{11–19}

Current indications of LPN are similar to those of OPN at centers where such expertise is available (Table 12.1). There is growing evidence to suggest that elective NSS (OPN or LPN) for tumors 4–7 cm (T1b) may be a reasonable option in select patients. The primary contraindication to LPN is lack of surgeon

Table 12.1 Indications for nephron-sparing surgery*Absolute indications*

Bilateral RCC

Tumor in a solitary kidney

Unilateral tumor with poorly/non-functioning contralateral kidney

Relative indications (contralateral kidney at risk for future compromise)

Hereditary RCC

Genetic diseases with risk of metachronous kidney cancer

Diabetes mellitus, hypertension, stone disease, or renovascular disease

Renal dysfunction

*Elective indications (normal contralateral kidney)*Renal tumor ≤ 4 cm

Indeterminate cyst with malignant potential

RCC, renal cell carcinoma.

experience and expertise with advanced laparoscopy. Other contraindications specific to LPN are uncommon, and include small tumor with a renal vein thrombus and a complex mid-pole completely intrarenal/hilar tumor in a patient with an absolute indication for NSS. Morbid obesity, prior open kidney surgery, and tumors 2 cm or larger in size increase the technical difficulty of LPN.

TECHNICAL CONSIDERATIONS

The principal technical challenge during LPN stems from the complexity of laparoscopic tumor excision and sutured renal reconstruction in a time-sensitive manner within acceptable warm ischemia limits. To add to the challenges of an already difficult operation is the somewhat reduced tactile input during laparoscopy, which reduces the margin for error. Indeed, successful LPN for complex tumors primarily requires an in-depth understanding of three-dimensional renal anatomy, an appreciation of visual clues during laparoscopy, as well as masterful ambidextrous handling of numerous laparoscopic instruments.

To minimize local recurrence, tumor excision with an adequate margin of normal parenchyma is essential. A negative margin is the primary criterion, with margin width having no practical consequence.²⁰ During LPN, a margin of approximately 0.5 cm is aimed for to prevent tumor violation. From a technical standpoint, achieving a bloodless field for tumor excision, pelvicaliceal repair, and renal hemostasis in a time-sensitive manner with minimal compromise of renal function are the specific technical considerations. Several promising

techniques are available at present, most geared towards improved hemostasis and collecting system repair.

Hemostasis

Achieving perfect hemostasis is the most important challenge during LPN. Several strategies have been developed for this purpose. These include conventional suture repair, tissue sealants, radiofrequency ablation, lasers, water-jet dissection, and microwave tissue coagulation.

A number of tissue sealants are commercially available including fibrin glues (Tisseel®, Baxter, Deerfield, IL, USA; Perioplast®, Behring, Marburg, Germany; Hemaseel®, Haemacure, Quebec, Canada; Crosseal®, Ethicon, Johnson & Johnson, Somerville, NJ, USA; Costasis®, Cohesion Technologies, Palo Alto, CA, USA; Dynastat®, Cohesion Technologies; Vivostat®, Vivolution, Blokken, Denmark), gelatin matrix thrombin sealant (FloSeal®, Baxter), human fibrinogen and thrombin fleece (Tachosil®, Nycomed, Rokskilde, Denmark; Tachocomb®, Nycomed), polyethylene glycol hydrogel (Coseal®, Baxter), cyanoacrylate glue (Dermabond®, Ethicon, Somerville, NJ, USA; GEM S.r.l., Viareggio, Lucca, Italy), bovine serum albumin and glutaraldehyde (Bioglue®, Cryolife Inc., Atlanta, GA, USA), and granulated mineral (Quickclot®, Z-Medica, Wallingford, CT, USA). The various fibrin sealants have small differences in adhesive, stretching, and hemostatic properties.

Breda et al examined the current practice patterns regarding the use of hemostatic agents during LPN in a multi-institutional study.²¹ Of 18 centers, 16 performed concomitant suturing/bolstering. The hemostatic agents and glues used included FloSeal, Tisseel, Bioglue, Glubran (GEM S.r.l. Viareggio, Italy), oxidized regenerated cellulose (Surgicel oxidized regenerated cellulose (Surgicel, Ethicon, Johnson & Johnson, Somerville, NJ, USA)), or combinations of these. Currently, our preference is for conventional sutured renal reconstruction using FloSeal and a Surgicel bolster as hemostatic adjuncts. We compared our results in patients undergoing LPN with adjunctive use of FloSeal with patients who underwent LPN without FloSeal.²² The FloSeal group was associated with decreased hemorrhagic complications (3% versus 12%) and significantly decreased overall complications (16% versus 37%).

Herrell and Levin evaluated the TissueLink® (TissueLink Medical, Dover, Delaware, USA) radiofrequency device during unclamped LPN in the laboratory setting and clinically in 25 patients.²³ Fibrin glue

was used as a hemostatic adjunct. There were no intraoperative complications. Mean estimated blood loss (EBL) was 98 ml (range 10–337). This device may have a role in unclamped LPN for small, peripheral, and exophytic tumors.

Several types of lasers have been tested for their ability to transect renal parenchyma while maintaining hemostasis. Ogan et al described a method of tissue soldering to achieve hemostasis and pelvicalyceal system (PCS) closure using the laser-mediated fusion of human albumin during LPN with hilar clamping in five pigs.²⁴ A 50% liquid albumin-indocyanine green solder was welded to the cut surface using an 810 nm pulsed diode laser (20 W). None of the acute or chronic kidneys developed extravasation, urine leak, or hematoma. One drawback of the technique was the necessity of hilar clamping.

Moinzadeh et al performed 12 LPN using an 80 W potassium-titanyl-phosphate laser (KTP) (GreenLight PVP™, AMS, MN, USA, Laserscope, San Jose, CA, USA) without hilar clamping in the calf model.²⁵ This initial study of laparoscopic KTP laser partial nephrectomy without hilar clamping confirmed its technical feasibility in most cases and good short-term outcomes. Lotan et al utilized a holmium:yttrium aluminum garnet (Ho:YAG) laser in ten porcine kidneys to transect the lower pole followed by placement of fibrin glue on the cut surface.²⁶ Blood loss was minimal, but extravasation was noted on retrograde pyelogram in two animals in the survival group. The use of lasers appears promising though clinical data are lacking.

Moinzadeh et al evaluated water-jet assisted (Helix Hydro-jet™, Erbe (Elektromedizina GmbH, Tuebingen, Germany), Marietta, GA, USA) LPN without renal hilar control in the survival calf model.²⁷ They were able to perform 18 of 20 cases without hilar control; with an EBL of 60 ml. Pelvicalyceal suture repair was necessary in five of ten chronic kidneys. However, no animal developed a urinary leak.

Until the ideal technique without hilar clamping has been developed in terms of hemostasis and pelvicalyceal repair, time tested techniques of sutured reconstruction will remain the reference standard.

Collecting system repair

Tumors adjacent to the collecting system requiring entry into the PCS during excision are not rare in our practice. We routinely insert a 5 Fr ureteral catheter in a retrograde fashion into the renal pelvis to precisely identify PCS entry. Desai et al prospectively compared

the perioperative outcomes of 27 LPN with pelvicalyceal entry with 37 LPN with no pelvicalyceal entry.²⁸ Both groups were comparable in terms of operating room (OR) time, tumor excision time, and EBL. However, pelvicalyceal suture repair was associated with a statistically significant longer warm ischemia time (WIT) and hospital stay. None of the patients undergoing pelvicalyceal suture repair developed urine leak. The results of this study showed that intentional entry into the PCS for tumors with intrarenal extension could be safely and efficiently repaired. We currently suture repair the PCS with a running 2-0 polyglactin suture, and test the integrity of the repair with a retrograde injection of dilute methylene blue.

Laparoscopic approach

Performance of advanced LPN consistently requires that the surgeon be confident in retroperitoneal and transperitoneal laparoscopy. The transperitoneal environment provides a larger working space, more recognizable anatomic landmarks, and technical ease of free-hand suturing. Although most tumors can be treated with the transperitoneal approach, some tumor locations may necessitate the retroperitoneal approach, specifically those located posteriorly or posteromedially. Angles for suturing in these locations are optimal with retroperitoneal access.

Wright and Porter compared 32 retroperitoneal with 19 transperitoneal LPN.²⁹ The choice of approach was based on tumor location. The retroperitoneal approach was associated with shorter OR time, decreased blood loss, quicker return of bowel function, and shorter hospitalization. They preferred the retroperitoneal approach for polar and posterolateral masses, and transperitoneal approach for anterior and medial lesions.

We retrospectively compared 100 transperitoneal with 63 retroperitoneal LPN.³⁰ In our series, blood loss, perioperative complications, postoperative serum creatinine, analgesic requirements, and histologic outcomes were similar in the two groups. The choice of approach is dictated primarily by surgeon experience and tumor location per se. Other factors include tumor size, number of tumors, number of arteries feeding the kidney, amount of visceral fat surrounding the kidney, and route of any prior open surgery on the quadrant of interest. At present, we favor the transperitoneal approach for all renal tumors except those that are located posteriorly or posteromedially specifically on the upper pole.

Renal ischemia and functional outcomes

Except for the most superficial and exophytic tumors, LPN requires a certain period of renal ischemia. Hilar clamping allows a near-bloodless surgical field with clear visibility to distinguish abnormal from normal tissue and facilitates safe tumor excision and subsequent renal reconstruction.

Guillonnet et al compared 12 patients undergoing LPN with hilar clamping with 16 patients without clamping (ultrasonic shears and bipolar cautery).³¹ Clamping the renal vessels was associated with decreased blood loss and shorter laparoscopic OR time.

Warm ischemia

The limit of safe renal WIT has generally been considered to be 30 minutes. This somewhat arbitrary number is derived from canine studies performed over two decades ago. Clearly, this issue needs to be revisited. Until then, maximum effort should be made to keep WIT as short as possible.

Laven et al assessed renal function recovery after prolonged WIT during laparoscopic versus open surgery in a solitary kidney porcine model ($n = 32$) by creating four subgroups (WIT of 30, 60, 90 minutes, and a 90-minute control group).³² At postoperative day 15, glomerular filtration rate (GFR) and serum creatinine values were not significantly different from baseline in any of the warm ischemia groups. Their results indicated that, in a single kidney porcine model, the renal unit could fully recover from WIT of up to 90 minutes. The same group tried to establish the upper limit for WIT in a single kidney porcine model ($n = 20$) by assigning four groups (120 minutes of open [$n = 5$] and laparoscopic [$n = 5$] WIT; five open and five laparoscopic controls).³³ Renal function did not return to baseline after 2 weeks, 66% of the animals showed significant renal insufficiency. This study demonstrated that 120 minutes of WIT exceeded the kidney's tolerance to ischemia in the porcine model.

Kane et al reported the impact of temporary arterial occlusion (TAO) during LPN on postoperative renal function in 27 patients, with arterial occlusion in 15 cases.³⁴ The preoperative and postoperative serum creatinine levels remained unchanged in patients with ($n = 15$) and without arterial occlusion ($n = 12$). The mean differential renal function of the operated kidney (49%) was similar to that of the contralateral kidney (51%) and this series demonstrated that TAO during LPN did not appear to affect short-term renal function adversely.

Bhayani et al evaluated the effect of variable durations of warm ischemia on long-term renal function in 118 patients undergoing LPN.³⁵ Patients were divided into three groups based on duration of warm ischemia: group 1, no renal occlusion ($n = 42$); group 2, warm ischemia for less than 30 minutes ($n = 48$); and group 3, warm ischemia for more than 30 minutes ($n = 28$). The authors found that warm ischemia up to 55 minutes was not associated with significant deterioration of serum creatinine.

Shekarriz et al assessed the impact of warm ischemia on renal function in 17 patients undergoing LPN.³⁶ Preoperative mean differential renal function and GFR in the affected kidneys were $50.20\% \pm 4.90\%$ and 75.56 ± 16.45 ml/min, respectively. At 3 months, differential renal function and GFR in the affected kidney were $48.07\% \pm 7.16\%$ and 72.03 ± 18.17 ml/min, respectively. The authors found a non-significant negative association between hilar clamping time and change in renal function, and a positive correlation between clamping time and change in GFR. The authors concluded that in patients with a contralaterally functioning kidney, temporary hilar clamping with a mean WIT of 22.5 minutes resulted in preservation of renal function in the affected kidney.

Cold ischemia

When longer ischemia times are expected cold ischemia is warranted, because renal hypothermia suspends renal metabolic activity at temperatures of $5\text{--}20^\circ\text{C}$.^{37,38}

The three main techniques described for laparoscopic renal hypothermia are surface cooling with ice slush, instillation of cold saline through a retrograde ureteral catheter, and intra-arterial perfusion of cold saline.^{39–41} Although all these techniques are clinically feasible and reasonably effective, they are rarely employed during clinical LPN. This is not only because of their complexity but also because the majority of tumors subjected to LPN do not require a long period of warm ischemia. On the other hand, there is no doubt that a safe, effective, reproducible, and user-friendly technique of laparoscopic renal hypothermia is likely to expand the indication for LPN further to include complex central tumors requiring delicate renal reconstruction.

Use of intraoperative ultrasound

The use of intraoperative ultrasound has been advocated to facilitate complex laparoscopic surgery. In our

Table 12.2 Our current technique of laparoscopic partial nephrectomy. Adapted from reference 43

Operative steps	Technical tips
Placement of a 5 Fr ureteral catheter into the renal pelvis	For precise identification of the site of pelvicalyceal entry and subsequent watertight repair Adequate padding
Patient positioning (transperitoneal approach: 45° flank position, retroperitoneal approach 90° lateral position)	
Identification of the renal hilum	Transperitoneal approach: en-bloc dissection of the vessels Retroperitoneal approach: precise identification, dissection, and mobilization of the renal vessels
Mobilization of the kidney and careful defatting of the kidney with special attention to maintaining perirenal fat over the tumor	Capsule should be intact for the renorrhaphy sutures
Intraoperative flexible ultrasound to delineate safe tumor margin limits	Score with J-hook cautery
Intravenous mannitol 12.5 g 15–30 minutes prior to hilar clamping and repeated dose of intravenous mannitol 12.5 g and furosemide 10–20 mg 2–3 minutes prior to unclamping	For pharmaco-renal protection
Hilar control	Transperitoneal approach: en-bloc clamping with Satinsky clamp Retroperitoneal approach: individual clamping with bulldog clamps
Cold-cut excision of the tumor and overlying fat and followed by subsequent control of the collecting system	Directing the curve of the endoshears away from the tumor
Random biopsies from the tumor bed for frozen section	If in doubt
Suture repair of the collecting system with a running 2-0 Vicryl on CT-I needle	Small amount of methylene blue injection to test the watertightness
Renal parenchymal repair with 1-0 polyglactin on a CTX needle over a pre-prepared Surgicel bolster (Johnson & Johnson, New Brunswick, NJ). Pre-placed Hem-o-lok clip 4 cm from the distal end of the suture serves as a pledget. Application of Floseal underneath the bolster in direct contact with the partial nephrectomy bed. Another Hem-o-lok clip is applied to the other suture end to compress the kidney	3–5 parenchyma sutures are usually adequate for hemostasis
Unclamping and inspection of the abdomen under no pneumoperitoneum	Clamp is opened but not removed yet for confirming absolute hemostasis
Removal of the specimen in an endocatch bag	Intact removal is essential
Placement of a JP drain (penrose drain for retroperitoneal approach)	5–7 days

experience, expertly performed real-time ultrasonographic demarcation of the tumor is extremely useful to plan resection during LPN, especially for intrarenal tumors. Fazio et al demonstrated that intraoperative ultrasound had a critical role in advanced laparoscopic surgery, specifically preventing positive surgical margin, identifying intrarenal tumors, excluding the presence of renal vein thrombus, and defining cystic lesions.⁴²

Our current technique of LPN (adapted from Aron and Gill⁴³) is described in Table 12.2. Critical steps of the procedure are demonstrated in Figures 12.1–12.5.

EXPANDING INDICATIONS

As laparoscopic techniques and technology advance, LPN is likely to be increasingly performed worldwide. With increasing laparoscopic confidence and experience many surgeons have attempted to expand the boundaries of laparoscopic renal surgery to include technically more challenging cases, which were once considered contraindications to the laparoscopic approach. Specific to LPN, these carefully expanded indications are discussed below.

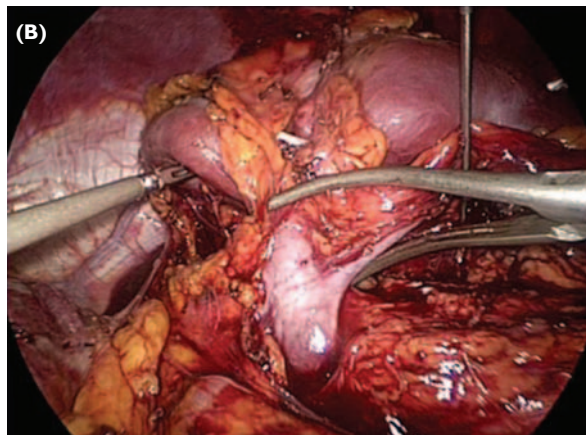
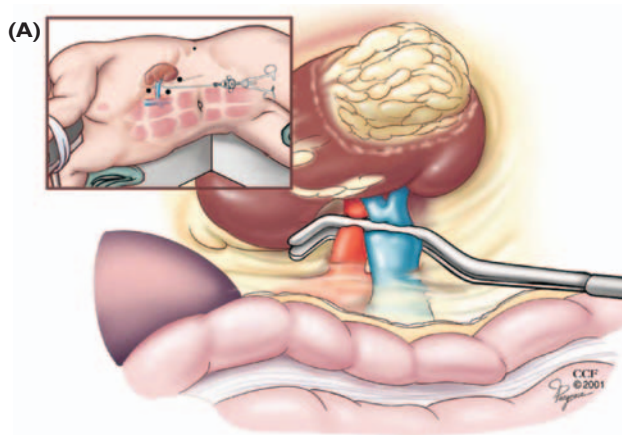


Figure 12.1 Hilar control. A laparoscopic Satinsky clamp is used for en bloc hilar clamping during transperitoneal approach. (A) Schematic, Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved. (B) Intraoperative image.

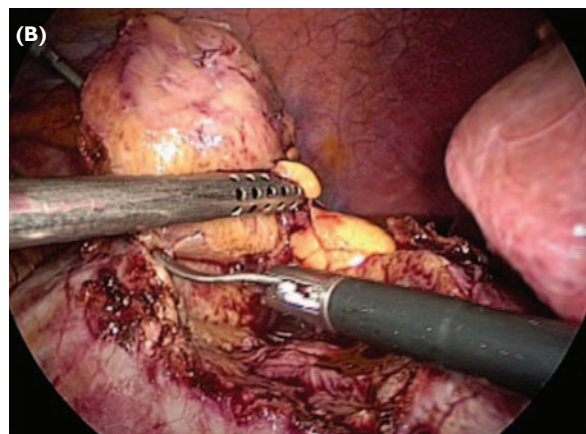
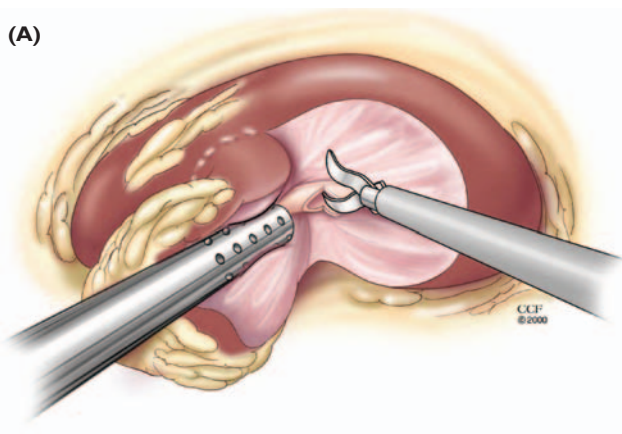


Figure 12.2 Tumor excision. The tumor and a surrounding rim of normal parenchyma is excised using cold endoshears. (A) Schematic, Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved. (B) Intraoperative image.

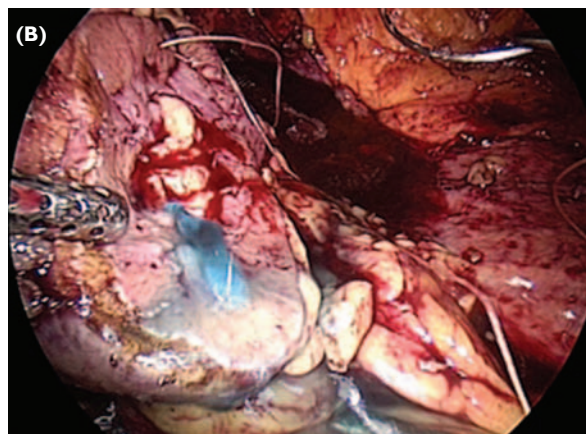
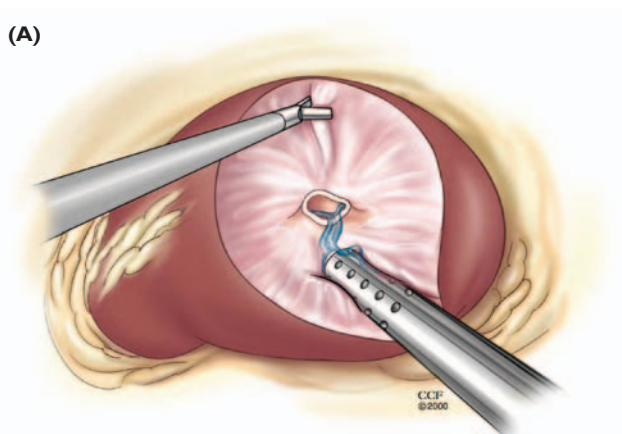


Figure 12.3 Methylene blue injection. Small amount of methylene blue is injected to test the watertightness. (A) Schematic, Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved. (B) Intraoperative image.

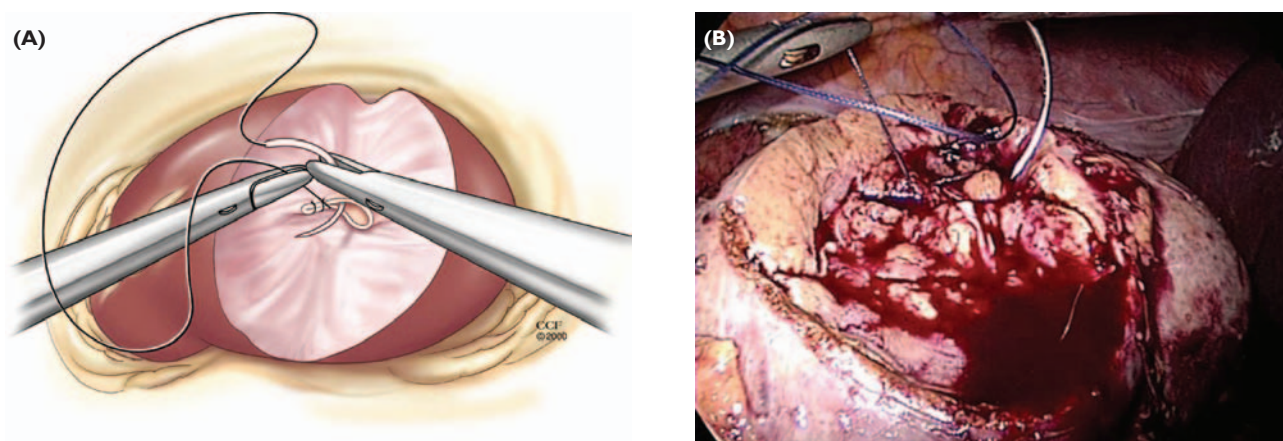


Figure 12.4 Pelvicalyceal system closure. The collecting system and divided blood vessels in the sinus fat are sutured using a running 2-0 vicryl stitch. (A) Schematic, Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved. (B) Intraoperative image.

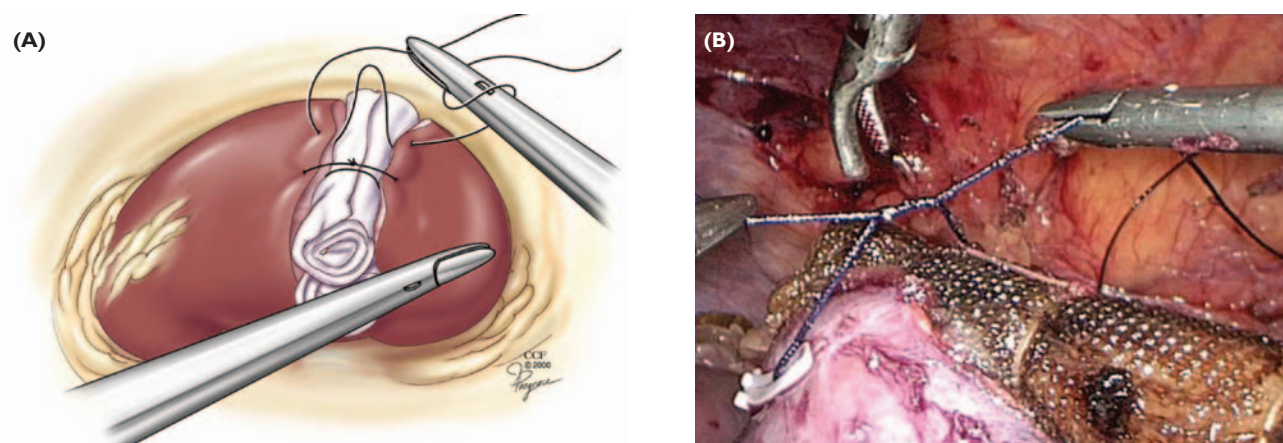


Figure 12.5 Renal renorrhaphy. Parenchymal renorrhaphy is performed using interrupted 1-0 polyglactin sutures tied over a surgical bolster. (A) Schematic, Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved. (B) Intraoperative image.

Adrenal involvement

From a technical standpoint, an upper pole tumor involving the adrenal gland may require LPN and concomitant adrenalectomy. Ramani et al published their results in four patients undergoing transperitoneal LPN and concomitant adrenalectomy for upper pole tumor with suspected adrenal involvement.⁴⁴ All patients were free of disease at a mean follow-up of 6.2 months. The adrenal was maintained en bloc with the partial nephrectomy specimen and the overlying fat and fascia. Technically, this requires dividing the adrenal vessels first, and completely mobilizing the upper pole of the kidney and adrenal outside Gerota's fascia prior to hilar clamping and partial nephrectomy.

Concomitant renal artery disease

Renal artery disease that coexists with RCC presents unique management issues, because precise identification, dissection, and mobilization of the renal artery and its branches are advanced laparoscopic maneuvers. Steinberg et al described the technical considerations of LPN in two complicated cases (one case with a solitary kidney) involving kidneys with renal arterial diseases.¹¹ The use of laparoscopic Doppler ultrasound was essential in such cases providing precise information regarding the location of the arterial features (i.e. course of the renal artery with respect to the intraluminal stent) and appropriate achievement of renal hilar control. Also, a specific Satinsky clamp (with an exaggerated curve) and additional clamps (bulldogs)

were used in these cases, avoiding damage to the stent integrity and safe control of the feeding vessels of the aneurysm, respectively. Collaboration of laparoscopic and radiologic teams helped the application of LPN in such demanding cases.

Anomalous kidneys

Horseshoe kidney is one of the most common renal anomalies. Molina et al reported the initial case of LPN in a horseshoe kidney for a 2 cm complex cystic renal mass in the right moiety.¹² Posterolateral location of the renal mass prompted the authors to approach the tumor retroperitoneoscopically. For anomalous kidneys, detailed preoperative radiologic evaluation of the renal vasculature using three-dimensional reconstruction of triphasic CT is necessary for surgical planning. The surgical approach depends primarily on the location of the tumor. Both types of vascular clamps, Satinsky and bulldog, need to be available on the instrument table.

Multiple tumors

Although radical nephrectomy is the reference standard in the presence of ipsilateral multiple tumors, NSS should be strongly considered in patients with solitary kidneys or bilateral renal tumors. Steinberg et al published their results in 13 patients (with an imperative indication in 92%) undergoing laparoscopic NSS for two or more ipsilateral renal tumors.¹³ LPN was performed in six patients either alone or in combination with laparoscopic renal cryoablation (LRC). After a mean follow-up of 16.4 months (range 1–54), there were no recurrences. In such cases, tumors can be excised either en bloc or separately. En bloc excision extended the WIT because of the greater degree of reconstruction required. Although an advanced technique, excising adjacent tumors can safely be performed by treating them as a single mass. In select cases, LRC was found to be a useful adjunct to LPN.

Heminephrectomy for large tumors

There is evidence to suggest that elective LPN for tumors 4–7 cm (T1b) may be a reasonable option in select (i.e. favorable tumor characteristics) and well-counseled patients.^{45–47} Our group has compared the outcomes of laparoscopic heminephrectomy in 41 patients requiring a resection of more than 30% of renal

parenchyma to a contemporary group of 41 consecutive patients who underwent LPN with less than 30% resection.¹⁴ Other than a longer WIT (39 versus 33 minutes) for laparoscopic heminephrectomy, there were no differences between the two groups regarding EBL, OR time, analgesic requirement, hospital stay, postoperative serum creatinine, and overall complications. All surgical margins were negative. Specific technical considerations inherent to laparoscopic heminephrectomy include achieving adequate surgical margins, routine entry into the PCS requiring meticulous repair, transection of large, deeply located intraparenchymal vessels, and securing durable renal hemostasis.

Cystic tumors

We believe LPN for a cystic mass is technically more challenging due to the greater risk of inadvertent cyst rupture and subsequent tumor spillage. We compared 50 patients undergoing LPN for a cystic renal lesion with 50 consecutive patients undergoing LPN for a solid renal mass.¹⁵ LPN was successful in all cases and intraoperative complications were similar in the two groups. All surgical margins were negative. However, one patient in the cyst group had retroperitoneal recurrence at 1 year despite negative margins. Extreme caution and a standard technique are recommended to avoid cyst rupture and local spillage during tumor mobilization and tumor excision in such cases. Notably, leaving an adequate margin of normal parenchyma is important. The use of laparoscopic ultrasound provided imaging the intracystic contents, measuring tumor dimensions and depth of parenchymal infiltration, and evaluation of the remainder of the kidney.

Hilar tumors

Tumors located in the renal hilum and in contact with major renal vessels have been considered by many groups to be a contraindication to LPN. In 2005, Gill et al reported the outcome of LPN for hilar tumors in 25 patients. Mean tumor size was 3.7 cm (range 1–10.3).¹⁶ LPN was successful in all cases without any open conversions or operative re-interventions. Hemorrhagic complications occurred in three patients (12%). Preoperative three-dimensional video reconstruction of triphasic spiral CT was invaluable in detailing the number, interrelationship, anatomic course, and position of the renal vessels in relation to the tumor. Secure repair of the PCS was one of the greatest challenges of LPN for hilar tumors.

Tumor in a solitary kidney

LPN for tumor in a solitary kidney is a technically and psychologically challenging operation. The margin for error is small. There is a specific need to suture fast and with great precision, while keeping WIT at a minimum.

Gill et al reported the largest series (22 patients) of LPN for tumor in a solitary kidney.¹⁷ Mean WIT was 29 minutes (range 14–55). Two cases (9%) were electively converted to open surgery. Median preoperative and postoperative serum creatinine (1.2 and 1.5 mg/dl) and estimated glomerular filtration rate (67.5 and 50 ml/min/1.73 m²) reflected a change of 33% and 27%, respectively. Important technical caveats include adequate intravenous hydration, reno-pharmacologic protection with mannitol and furosemide, minimal ischemic insult, and established standard technique.

Central tumors

Centrally located tumors typically require precise intracorporeal suturing and complex reconstruction in a time-sensitive manner. The technical complexity of such cases depends on where the central tumor is located and what kind of suturing angles are available, especially as regards the dominant hand. Frank et al compared LPN for central tumors ($n = 154$) with LPN for peripheral tumors ($n = 209$).¹⁸ Central tumors were defined as those abutting or invading the collecting system on preoperative CT. Although EBL was similar, central tumors required longer OR time, WIT, and hospital stay. There was one positive margin in each group. However, there were more early postoperative complications in the central group.

Incidental tumors pT2 or higher

Ukimura et al reported results of LPN in patients with an incidentally detected stage pT2 ($n = 1$), pT3a ($n = 19$), and pT3b ($n = 1$) tumor in 21 patients.¹⁹ Accurate staging was not possible by preoperative CT or intraoperative ultrasound in this cohort. However, all resection margins were negative for cancer. In the one case with stage T3b, detection of tumor invasion of a renal vein branch resulted in conversion to laparoscopic radical nephrectomy. During a mean follow-up of 29 months (range 1–58), the cancer-specific survival was 95%. In order to avoid a positive margin and a potential local recurrence, it is of critical importance to routinely excise the overlying fat en bloc with the tumor per se.

Obese patients

Obesity is associated with an increased risk of RCC and surgical management of obese patients is associated with a greater risk of intraoperative and postoperative complications.^{48,49} Therefore, until recently obesity was considered a relative contraindication for LPN. Our group has compared the operative data and postoperative complications of 140 obese (BMI >30 kg/m²) and 238 non-obese (BMI ≤30 kg/m²) patients.⁵⁰ LPN was performed safely in obese patients with a perioperative complication rate similar to that of non-obese patients. The retroperitoneal approach was associated with a shorter OR time and hospital stay in the two groups. In the obese group, we positioned the trocars more lateral and more cephalad (closer to the kidney). Also, a Carter-Thomason device was used exclusively to close the large (>5 mm) trocar sites.

Intraparenchymal tumors

The management of intraparenchymal tumors represents a technical challenge because there are no external visual clues for tumor localization or excision, and pelvicalyceal repair and hemostasis are difficult to accomplish. We have evaluated the outcomes of completely intraparenchymal tumors in 23 patients (unpublished data). The median tumor size was 2.2 cm (range 1.3–7.7). Almost all (96%) patients had pelvicalyceal entry and subsequent repair. There were two intraoperative hemorrhagic complications managed laparoscopically. Effective utilization of intraoperative ultrasound was the key for successful laparoscopic performance (i.e. tumor excision).

After previous surgery

Prior ipsilateral renal surgery is considered a relative contraindication for LPN, because of the likelihood of dense adhesions and distorted tissue planes. We have performed 25 LPN (16 transperitoneal, nine retroperitoneal) after previous ipsilateral renal surgery.⁵¹ Mean tumor size was 2.5 cm (range 1–5.6), interval from previous surgery was 6.6 years (range 0.3–34), and WIT was 35.8 minutes (range 22–57). We believe LPN can be technically challenging after prior surgery and adequate experience is necessary for good outcomes. Careful planning of port placement, meticulous dissection around the hilum, and establishing a standard protocol during surgery are the principal considerations for successful LPN.

COMPLICATIONS

LPN is a complex procedure with potential for urologic and non-urologic complications. We have recently assessed LPN complications in a contemporary cohort of 200 patients.⁵² In our initial cohort, technique-related urologic complications of hemorrhage (9.5%) or urine leak (4.5%) occurred in 27 patients.⁵³ Open conversion was required in two patients (1%) and re-exploration laparotomy in four patients (2%). Compared with previously reported data, with our increasing experience and refinement of techniques, the latter cohort demonstrated that overall (from 33% to 19%), urologic (from 18% to 8%), and non-urologic (from 15% to 11%) complication rates have decreased significantly, despite an increase in tumor complexity. Furthermore, hemorrhage and urine leak rates decreased to 4.5% and 2%, respectively.

We also analyzed our aggregate experience with LPN to determine the incidence and risk factors for postoperative complications in 507 procedures (unpublished data). Various patient, tumor, intraoperative, and technical factors were evaluated. In multivariate analysis, increased EBL, presence of solitary kidney, increased WIT, and transperitoneal approach compared to retroperitoneal approach were identified as independent predictors of overall postoperative complications. In contrast, use of Floseal almost halved the incidence of overall complications.

Israel et al reported CT and magnetic resonance imaging findings of partial nephrectomy related complications.⁵⁴ Unquestionably, familiarity with radiologic findings of such complications will allow accurate diagnosis and appropriate management in today's era of 'maximum nephron preservation'.

ONCOLOGIC OUTCOMES

LPN is increasingly becoming a definitive therapeutic option in patients with small renal mass. Current global experience with LPN exceeds 2000 cases, of which more than 700 have been performed at the Cleveland Clinic. Lane and Gill have recently published a preliminary report in the literature regarding 5-year oncologic and functional outcomes of LPN.⁵⁵ Of the 557 LPNs performed at the Cleveland Clinic, 58 patients with a localized tumor have completed more than 5 years since surgery.⁵⁴ At a median follow-up of 5.7 years there was only one local recurrence and no distant metastasis. No patient with normal serum creatinine undergoing elective LPN developed chronic

renal insufficiency. Overall and cancer specific survival were 86% and 100%, respectively.

Permpongkosol et al assessed the outcomes of postoperative positive surgical margin (PSM) in 511 patients undergoing LPN in two reference centers.⁵⁶ There were nine patients (1.8%) with a PSM on final pathology. Two patients underwent completion radical nephrectomy, while seven elected surveillance. Only one patient died of metastatic disease and the remaining eight patients were free of disease at a median follow-up of 32 months (range 6–76).

Perioperative and oncologic outcomes from select LPN studies are listed in Table 12.3.

We have recently compared the outcomes of LPN ($n = 771$) with those of OPN ($n = 1029$) in 1800 patients treated for a single renal tumor in three tertiary referral institutions (unpublished data). OPN patients comprised a higher risk surgical group with older patients, larger tumors, and more solitary kidneys. LPN was associated with reduced operative blood loss, shorter operative time, and shorter hospital stay. WIT was approximately 10 minutes longer during LPN. Despite the somewhat longer WIT, renal functional outcomes were similar between the LPN and OPN groups, with 97.9% and 99.6% of renal units maintaining function. Intraoperative complications were comparable, while postoperative complications were more common after LPN (18.6% versus 13.7%). Positive surgical margins for RCC were similar (1.6% versus 1%). Oncologic outcomes were similar as well: local recurrence was 1.4% versus 1.5% and distant recurrence was 0.9% versus 2.1% for LPN and OPN, respectively. Three-year estimated cancer-specific survival was 99.3% and 99.2% in the two groups, respectively.

FUTURE PERSPECTIVES

In order to further expand indications for LPN as well as disseminate the technique worldwide, the technical complexity of the procedure needs to decrease, and a reliable method of decreasing or eliminating warm ischemia needs to be developed. Currently, there is no reliable alternative to advanced laparoscopic suturing to achieve secure hemostasis and PCS closure. Novel hemostatic-urinary sealants could make this a reality in the future, especially for peripheral superficial lesions. Unclamped LPN is not a reality today, except for the most superficial lesions. Whether laser excision or water-jet dissection could make this possible in the future remains to be seen. Advances in intraoperative imaging and surgical navigation may be of value to

Table 12.3 Outcomes of laparoscopic partial nephrectomy from select series

	No. of patients	Mean tumor size (cm)	Warm ischemia time (min)	Mean estimated blood loss (ml)	Select complications	No. of positive surgical margins	Mean follow-up (months)	Local recurrence	Port site recurrence	Cancer-specific survival (%)
Jeschke et al, 2001 ⁵⁷	51	2 (1–5)	All unclamped	282 (20–800)	Hemorrhage 2% Urine leak 5.9%	0	34.2	—	—	100
Allaf et al, 2004 ⁵⁸	48	2.4 (1–4)	NA	NA	NA	1 (2.1%)	37.7	2 (4.2%)	—	100
Abukora et al, 2005 ⁵⁹	78	2.27 (0.6–3.5)	33.8 (warm ischemia n = 25, cold ischemia n = 24, without ischemia n = 29)	Without clamping 254 With clamping 212	Hemorrhage 3.8% Urine leak 3.8% Urinary fistula 2.6%	1 (1.3%)	12.2	—	—	NA
Wille et al, 2006 ⁶⁰	44	2.8 (1–5)	21 (warm ischemia n = 25, unclamped n = 19)	NA	Hemorrhage 4.5% Urine leak 4.5%	0	15	—	—	NA
Weld et al, 2006 ⁶¹	60	2.4 (0.7–5.1)	26.9	225	Hemorrhage 3.3% Urine leak 8.3%	0	25.3	—	—	NA
Simmons and Gill, 2006 ⁶²	200	3.0 (0.9–10.3)	34.7 (8–60)	234 (25–2500)	Hemorrhage 4.5% Urine leak 2%	2 (1%)	NA	—	—	NA
Lane and Gill, 2007 ⁶⁵	56	2.9 (1.3–7)	NA	NA	Hemorrhage 5.4% Urine leak 1.8%	1/37 (2.7%)	68	1/37 (2.7%)	—	100

NA, not available.

guide tumor excision in real time in order to minimize chances of a positive margin while maximizing nephron preservation.

CONCLUSIONS

NSS is currently the preferred treatment for a small renal mass. OPN has established the fundamental principles of NSS and has been the reference standard. LPN offers perioperative and oncologic outcomes comparable with those of OPN, while reducing patient morbidity. LPN, duplicating the principles and outcomes of OPN, appears to be the future. LPN is the minimally invasive procedure of choice for NSS and the technique has become standardized. Preliminary 5-year oncologic data for LPN are available and outcomes appear similar to OPN. LPN will likely become the favored option for the majority of T1 renal tumors in the near future, while OPN will be reserved for patients with a tumor that requires complicated excision and reconstruction.

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13 Surgery for renal vascular disease

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INTRODUCTION

The introduction of endovascular transluminal techniques for treating arterial stenosis has had a profound impact on the role of surgery for renal artery stenosis (RAS). The majority of patients with renal artery disease are currently treated with percutaneous transluminal angioplasty and intra-arterial stents. Open surgical revascularization remains the best option for patients with branch renal artery disease, renal artery aneurysm, or in cases of failed or complicated endovascular procedures. When used in properly selected patients, open surgical revascularization provides excellent long-term outcomes in patients with renal artery disease.¹ Atherosclerosis accounts for most cases of RAS, while fibrous dysplasia accounts for fewer cases. Other rare causes include renal artery aneurysm, arteriovenous malformations, neurofibromatosis, middle aortic syndrome, and Takayasu arteritis.

INDICATIONS FOR SURGERY

Renovascular hypertension (RVH) has been the traditional indication for surgery to repair RAS. More recently, renal dysfunction resulting from RAS (ischemic nephropathy) has become recognized as another indication for renal revascularization. RVH and ischemic nephropathy can be present independently or concomitantly in the same patient. Clinical clues to suggest RVH include sudden onset and short duration, patient age less than 30 or more than 50 at the onset of disease, presence of systemic vascular disease, end organ damage such as left ventricular hypertrophy or severe retinopathy, and renal function deterioration in response to treatment with angiotensin-converting enzyme inhibitors.

Intra-arterial contrast angiography remains the definitive diagnostic study, and is necessary for planning surgical or endovascular intervention. Only lesions with hemodynamic significance (more than 70% stenosis) should be treated. In patients with fibrous dysplasia, angiography defines the type and extent of the lesions. This information is necessary to guide

treatment and predict the natural history of the disease.^{2,3} Most patients with fibrous dysplasia are diagnosed with medial fibroplasia, which rarely progresses to loss of kidney function or complications, and can be safely managed with medical treatment. Patients with intimal and perimedial fibroplasias usually have severe hypertension, and have a tendency to progress to dissection, thrombosis, and loss of renal function. Intervention for revascularizing such lesions is usually recommended as an early treatment. Percutaneous angioplasty has excellent success rates⁴ in the range of 90–95%. In these cases surgery is reserved for patients with branch disease, associated renal artery aneurysm, or angioplasty failures.

Patients with RVH secondary to renal artery atherosclerosis (ASO) have a poorer blood pressure response to revascularization, with cure rates around 20% only, although the majority will have some improvement of blood pressure control. Medical management should be aggressively pursued in these patients. Endovascular management for ASO usually includes stent placement to improve patency rates. Surgical repair of these lesions is indicated for (uncommon) branch disease, and failed or complicated stent placement.

Ischemic nephropathy

This is defined as the development of renal insufficiency from renal artery ASO, and occurs when there is high grade (more than 75%) stenosis involving the entire renal mass. This entity is separate and distinct from RVH, although the two may coexist. Ischemic nephropathy usually occurs in older patients with generalized ASO. Renal artery ASO is progressive,³ and eventually results in complete loss of renal function of the affected unit. Revascularization in such cases is warranted to improve or stabilize renal function. Clinical clues to the existence of ischemic nephropathy include unexplained azotemia in an older patient, azotemia associated with angiotensin-converting enzyme inhibitor use, diminished renal size, and presence of atherosclerotic disease in extrarenal sites (cerebrovascular, coronary, or peripheral vascular disease).

PREOPERATIVE PREPARATION

Precise anatomic delineation of the arterial lesion by intra-arterial angiography is necessary for planning and performing surgical revascularization. Careful evaluation of the aorta, the iliac arteries, as well as the origins of the celiac and superior mesenteric arteries (on lateral aortogram) is required to determine the optimal donor artery for revascularization. Correction of coronary or carotid disease preoperatively is essential to decrease morbidity and mortality in the perioperative period.⁶ Patients should be well hydrated before surgery, and hypotension should be avoided intraoperatively and in the postoperative period, to minimize the possibility of graft thrombosis. A postoperative stay in an intensive care unit may be necessary for a day or two to manage postoperative fluctuations in blood pressure.

PATIENT POSITIONING

Revascularization of the kidney is most commonly performed through an anterior transperitoneal approach, which provides the best access to major vessels for vascular control. Consequently, patients are usually placed in the supine position. To allow harvesting of the saphenous vein, the patient is also placed in a mild frog-legged position, which provides access to the anteromedial aspects of both thighs. The abdomen, lower chest, and upper thighs should be shaved and prepped, with sterile surgical field allowing access to abdomen, both groins, and both thighs.

A subcostal or a midline incision can be used. Midline incisions are versatile, allowing access to the renal vessels, as well as the whole length of the abdominal aorta, the iliac arteries, and the hypogastric artery to be harvested for use as a graft. Autotransplantation of the kidney can be performed through a midline incision as well. A right or left subcostal incision provides excellent access to the renal hilar area and the abdominal aorta, allowing easier reflection of the colon, and is a suitable incision for most renal bypass procedures, except iliorenal bypass.

AORTORENAL BYPASS

Aortorenal bypass graft is an attractive and straightforward renal revascularization technique. The aorta makes the best donor vessel for revascularization, with strong outflow. The required dissection is fairly simple,

exposing aorta from the level of the renal arteries to the inferior mesenteric artery. The aorta is commonly involved with atherosclerotic disease, which limits the application of aortorenal bypass in cases of atherosclerotic RAS. In this circumstance, care must be taken to ensure that a relatively disease-free portion of the aorta is used for the proximal arterial anastomosis, or an extra-anatomical bypass procedure should be performed. On the left side, using the lower thoracic aorta (which is rarely affected by ASO) as a thoracic aortorenal bypass procedure can also be performed.

The best results for revascularization are obtained with autologous arterial grafts that withstand arterial pressure without long-term deterioration. The arterial graft most commonly used is the hypogastric artery.⁷ Its use is limited by short length, making it unsuitable when a long graft is needed, or on the right side. Another limitation is the early affection of the hypogastric artery by ASO, which also makes it unsuitable for use. Venous grafts also offer good results, and have proven durability.⁸ The saphenous vein is the most commonly used, being easy to procure, and of sufficient length for all required procedures. Aneurysmal dilatation of saphenous vein grafts can occur long term, such change is more common in children, and precludes the use of saphenous vein in this group of patients. If no autologous material is available, a synthetic graft of polytetrafluoroethylene or Dacron may be used.⁹

Exposure for a right sided aortorenal bypass is accomplished by mobilizing the right colon, and Kocherizing the duodenum. The liver is retracted superiorly, and the inferior vena cava as well as the aorta are exposed. A self-retaining ring retractor is essential to maintain this exposure. The anterolateral surface of the aorta is dissected, facilitated by lateral retraction of the inferior vena cava, and superior retraction of the left renal vein. Dissection along the right side of the aorta in a cephalad direction leads to the origin of the right renal artery posterior to the left renal vein. The renal artery is dissected behind and lateral to the inferior vena cava by retracting the cava and the right renal vein. The renal artery is dissected distally towards the kidney, with the branches dissected as required from preoperative angiography.

A suitable donor area of the aorta is selected, and an appropriate length of saphenous vein harvested. This length should be more than the anticipated length, and it should not be trimmed to proper length until it is time to perform the distal anastomosis.

The proximal (aorta graft) anastomosis is performed first. Vascular control of the aorta around the selected

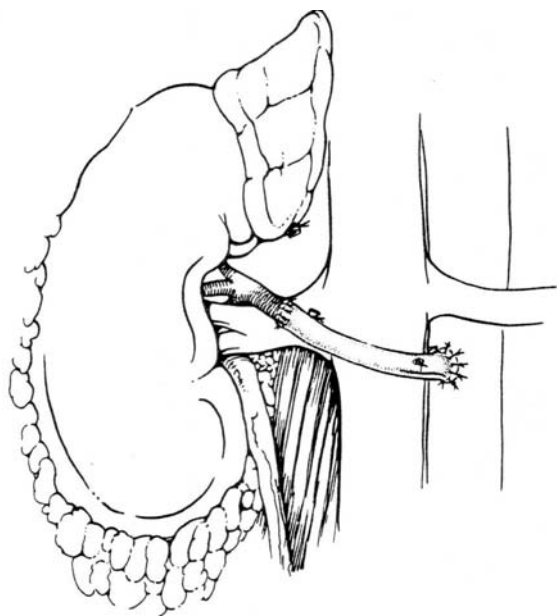


Figure 13.1 Completed right aortorenal bypass.

donor site can be obtained by cross clamping, or side clamping with a Satinsky clamp. The aortotomy should be oval in shape, and placed on the anterolateral aspect of the aorta to allow a gentle curve over the vena cava without proximal kinking or angulation. The vein graft is spatulated for a short distance, and an end-to-side anastomosis is performed. We prefer interrupted vascular silk sutures (5-0 or 6-0) on the anterior and posterior walls after two apical sutures are placed, a continuous suture line using Prolene is commonly used as well.

The vein graft is then clamped with a bulldog clamp, and the aortic clamps are released, heparinization is reversed. The renal artery is ligated proximally, and clamped distally with a bulldog clamp after injecting heparinized saline into the kidney. Trimming of the vein graft should be done to allow enough length for a tension-free anastomosis without any redundancy that may predispose to kinking and thrombosis. The distal anastomosis is then performed in an end-to-end fashion. Interrupted or continuous suture can be used, although narrowing tendency is minimized using interrupted sutures. The distal and proximal clamps are removed, and blood flow to the kidney is restored (Figure 13.1).

For the left side, the descending colon and the splenic flexure are mobilized to expose the renal hilum and the aorta. The renal artery is identified on the lateral aspect of the aorta. The donor site is chosen on the lateral aspect of the aorta on the left side, instead of anterolaterally on the right. The shorter

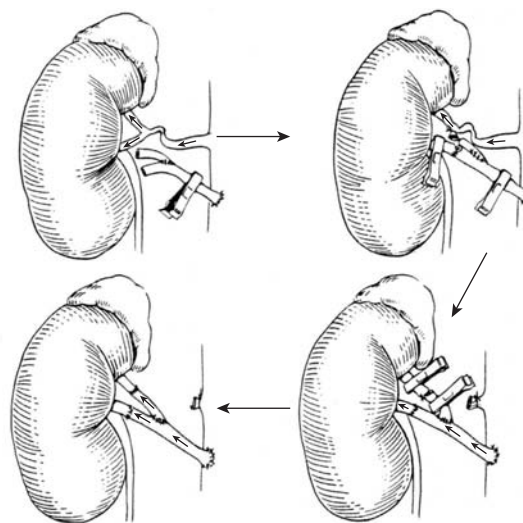


Figure 13.2 Aortorenal bypass with branched saphenous vein graft.

graft distance on the left side makes the hypogastric artery more useful.

Patients with multiple renal arteries or disease involving the branches of the renal artery outside the renal hilum can be revascularized with a branched graft in situ. This technique is also used for patients with renal artery aneurysm that extends into the extra-hilar portion of the renal artery branches.¹⁰ The saphenous vein provides good material for branched grafts, as it has sufficient length, and can be fashioned into any desired configuration.¹¹ The hypogastric artery can be harvested with its branches and used on the left side. Such branch anastomoses are usually delicate, and finer suture (7-0) is required. Optical magnification is essential for branch anastomosis. Ligation of the renal artery branches and anastomosis is performed one by one. The remainder of the kidney remains perfused through the renal artery while the branch anastomosis is performed, limiting the overall renal ischemia time (Figure 13.2).

EXTRA-ANATOMIC BYPASS TECHNIQUES

It may not be possible to perform an aortorenal bypass in a variety of situations. These include older patients with aortic atherosclerosis, aortic aneurysm, or fibrosis from previous surgery. In these cases, a renal artery bypass that avoids utilizing the abdominal aorta is safer. The morbidity of these extra-anatomic renal bypass procedures alone is significantly lower than the morbidity of a combined aortic replacement and renal

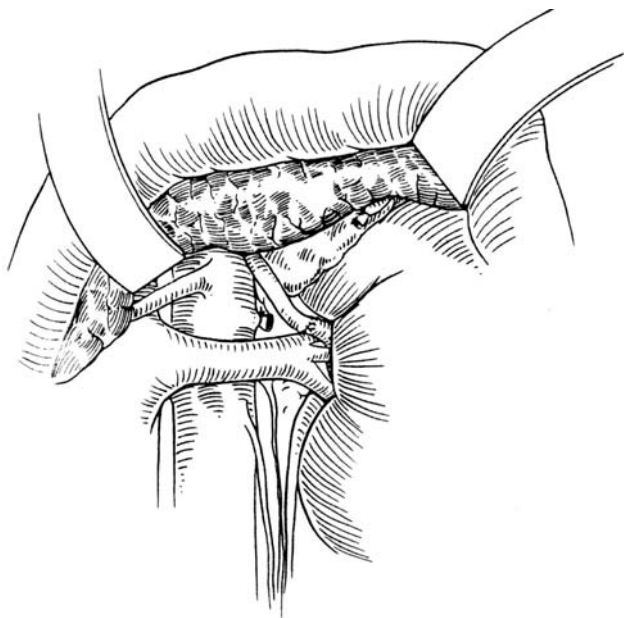


Figure 13.3 Splenorenal bypass.

revascularization, and the success rates are quite high.¹² Such alternate bypass techniques are splenorenal, hepatorenal, and iliorenal bypass procedures. These potential donor arteries need to be evaluated radiographically before surgery by lateral aortography to show the celiac axis, as well as pelvic angiography to evaluate the iliac vessels.

Splenorenal bypass

Splenorenal bypass is a useful bypass procedure for patients with a difficult aorta who need left renal revascularization.¹³ The procedure has several advantages including surgery away from the aorta, the absence of graft material, a single arterial anastomosis, and close proximity of the splenic artery to the renal artery, both of which have a similar caliber. The procedure is generally considered to be unsuitable for right renal revascularization (Figure 13.3).

Exposure of the renal artery is performed in the usual manner. The splenic artery is identified cephalad to the splenic vein, behind the body of the pancreas. The splenic artery is dissected proximally and distally to allow enough mobility to reach the renal artery. A bulldog clamp is placed on the splenic artery proximally, and it is ligated and divided distally. There is no need to perform a splenectomy, as the spleen will remain adequately vascularized through collateral arterial supply from the short gastric arteries. The splenic artery is irrigated free of blood and debris with heparinized saline. The splenic artery is trimmed to the correct length,

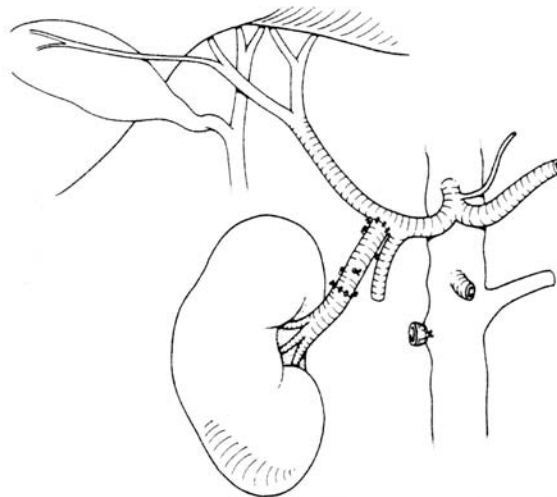


Figure 13.4 The most common method of performing hepatorenal bypass: vein graft anastomosed end-to-side to the common hepatic artery.

taking into consideration the elongation of the artery that occurs with distention, as well as shortening of the gap between the two vessels as self-retaining retractors are removed and the pancreas replaced anterior to the renal hilum. The anastomosis to the distal renal artery is performed. We prefer to use an interrupted end-to-end technique with 6-0 vascular silk. End-to-side anastomosis of the splenic artery to the renal artery is more difficult, and associated with suboptimal hemodynamic flow. Continuous suture line using fine Prolene can also be performed. Finally, the bulldog clamps are released, and the anastomosis checked for hemostasis and blood flow into the distal renal artery (Figure 13.4).

Hepatorenal bypass

Hepatorenal bypass is a useful technique for right renal artery revascularization when an aortorenal bypass is not possible.¹⁴ The liver derives a dual blood supply through the hepatic arterial and portal venous systems, with the hepatic artery contributing about 20% of the blood supply to the liver. Anatomic variation of the hepatic arterial tree is common, with separate origins of the right and left hepatic arteries from the superior mesenteric or left gastric artery being the most common anomaly.

Different techniques can be used for hepatorenal bypass according to the anatomic findings and the caliber of the hepatic vessels. Most commonly a saphenous vein graft is used in an end-to-side fashion to the common hepatic artery and an end-to-end fashion to the renal artery (Figure 13.4). Other variants include end-to-end

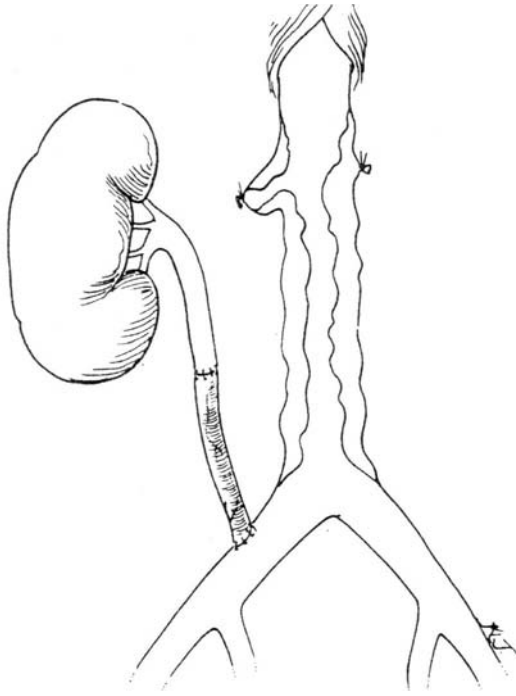


Figure 13.5 Iliorenal bypass.

anastomosis to the common hepatic, right hepatic, or gastroduodenal artery, with or without an interposition saphenous vein graft, as length permits. In such cases, the liver does not suffer ischemic damage, but the gallbladder needs to be removed to minimize the risk of necrosis. When using the gastroduodenal artery, care must be taken to avoid proximal kinking at the origin, as well as direct injury to the duodenum or pancreas.

Iliorenal bypass

Iliorenal bypass is a technique that can occasionally be used when it is not possible to perform an aortorenal, hepatorenal, or splenorenal bypass.¹⁵ Occasionally the iliac artery will be relatively healthy in the presence of aortic atherosclerosis, although such disease can progress to involve the iliac vessels and compromise the bypass graft at a later time. The procedure is equally useful for the right and left sides, and the bypass is carried out using a long reversed saphenous vein graft (Figure 13.5).

EX VIVO REPAIR WITH AUTOTRANSPLANTATION

Ex vivo microvascular repair and autotransplantation is a useful revascularization technique that is used when arterial disease extends into the smaller branches of the

renal artery.¹⁶ Such branches are usually small, and disease may extend into the renal sinus making in situ repair difficult. Branch renal artery disease is usually caused by fibromuscular dysplasia, arteriovenous fistula, renal artery dissection, and renal artery aneurysm. The advantages of the technique include optimum exposure and illumination, a bloodless field, greater renal protection from ischemia, and easy use of optical magnification and microvascular technique. The non-perfused kidney is softer, allowing distal dissection of the renal artery branches a lot further into the renal sinus.

The extent of renal artery disease has to be fully delineated before surgery. Patients with severe aortoiliac atherosclerotic disease, or with kidneys with parenchymal or diffuse small vessel disease, are not candidates for this approach. Such diseased kidneys perfuse poorly after removal, resulting in irreversible ischemic damage.

Surgery is usually performed through two separate incisions, for the kidney removal and for the autotransplantation. In thinner patients, a single long midline incision can be used for both parts of the operation. Adequate perfusion of the kidney and brisk urine output before nephrectomy is essential, similar to live donor nephrectomy. The kidney is flushed with cold perfusate immediately after nephrectomy, and kept in an ice slush filled basin throughout the extracorporeal reconstruction.

Microsurgical instruments and optical magnification are essential, as well as careful technique to avoid injuring the delicate renal hilar vessels. After the full extent of disease is delineated and dissected, a graft material is chosen. If available and healthy, a hypogastric artery graft, harvested intact with its branches, can provide an optimal graft material. A long segment of saphenous vein can be used as well, multiple vein segments can be anastomosed end-to-side to the main vein, allowing a branched graft to be fashioned in any configuration. Fine suture material (7-0 to 9-0) and interrupted suture technique are used for such anastomoses. After the repair is complete, the kidney is autotransplanted into the renal fossa, and a ureteroneocystostomy is performed (Figure 13.6).

POSTOPERATIVE CARE AND COMPLICATIONS

Patients undergoing renal artery revascularization should be monitored in the intensive care unit postoperatively. Wide blood pressure fluctuations are common, and can predispose the patient to bleeding or graft thrombosis. Diastolic blood pressure should be

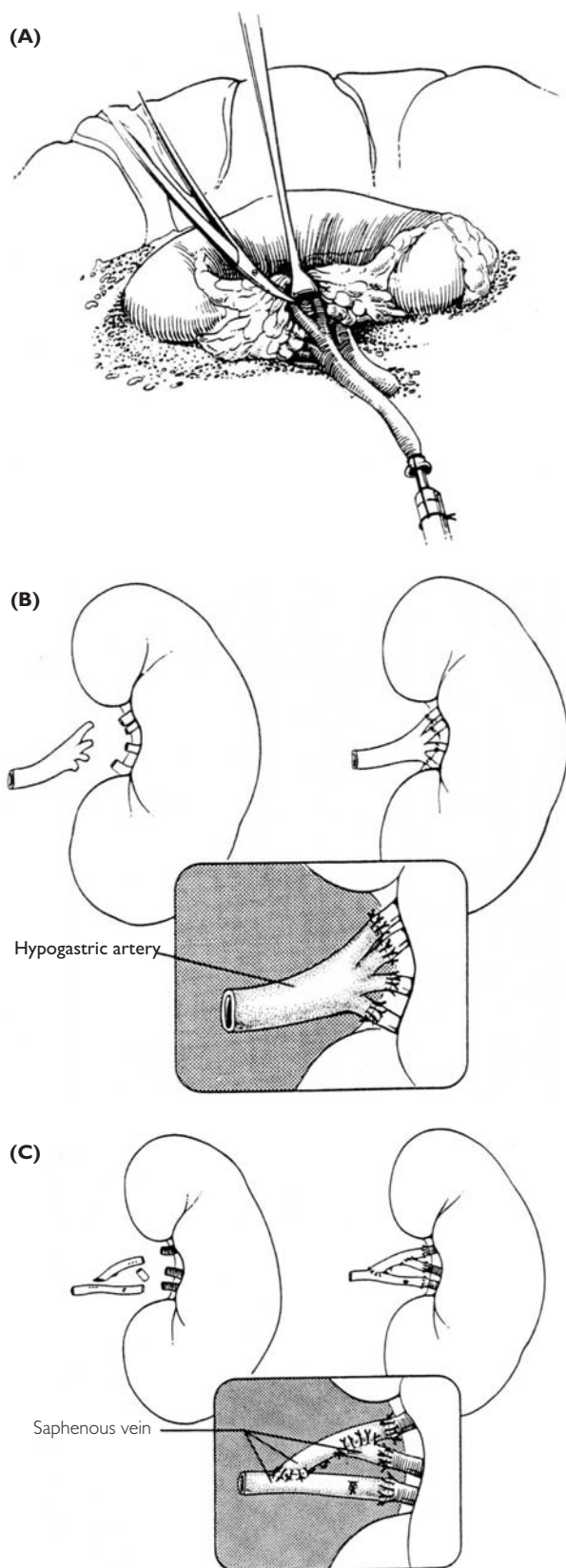


Figure 13.6 Extracorporeal microvascular repair of branch renal artery disease. (A) Renal artery branches dissected into the renal hilum under hypothermia. (B) Repair with branched hypogastric artery graft. (C) Repair with branched saphenous vein graft.

maintained around 90 mmHg using short acting intravenous antihypertensive medication or pressors as needed. A renal scan is performed 24 hours after surgery to confirm perfusion of the kidney.

Postoperative bleeding usually occurs within the first 24 hours, and is detected by changes in vital signs and blood counts. Management depends upon the estimated severity, and ranges from conservation with blood transfusion to re-exploration with repair of the bleeding anastomosis or vessel.

Graft thrombosis is estimated to occur in 2–4% of cases. It should be suspected when a postoperative renal flow scan shows no perfusion to the kidney, or severe unexplained hypertension develops suddenly. Attempts at salvage are rarely successful, nephrectomy may be required for severe hypertension.

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14 Interventional radiology for renovascular disease

Michael A Geisinger

Over the past two decades, minimally invasive procedures for the treatment of renal artery stenosis (RAS) have been developed based on percutaneous transarterial catheter techniques. These catheter-based interventions of balloon angioplasty and arterial stent placement have resulted in a significant decline in the number of open surgical revascularization procedures. The determination of which interventional approach to perform, balloon angioplasty or stent placement, is dependent to a large extent on whether the etiology of the stenosis is atherosclerosis or fibromuscular dysplasia. Atherosclerosis is by far the most frequent cause of renal artery stenosis, accounting for approximately 90% of cases, with fibromuscular dysplasia responsible for most of the remaining 10%.

INTERVENTION FOR ATHEROSCLEROSIS: RENAL ARTERY STENTING

Atherosclerotic stenoses typically involve the ostium and/or the adjacent proximal portion of the renal artery. These lesions consist of intimal plaques that can be covered by a fibrous cap or can be ulcerated and contain patches of adherent thrombus. Balloon angioplasty was the first percutaneous interventional treatment to be commonly employed, but the results were disappointing with restenosis occurring in nearly half of the patients. The high restenosis rate of ostial lesions after balloon angioplasty was attributed in part to atherosclerotic plaque in the aorta engulfing the renal artery origin, with the plaque eventually resuming its former shape when the balloon was deflated. The eccentric location and elastic quality of proximal renal artery lesions were other factors cited for the unsatisfactory results. These various factors were largely addressed with the advent of the vascular stent. Placement of a stent across an ostial or proximal atherosclerotic lesion results in a marked improvement in caliber, and ultimately in improved longer-term patency. While there is no definite consensus on which patients with atherosclerotic renal artery stenosis to treat, the two most frequently stated justifications are to improve control of hypertension and to preserve renal function.

Hypertension

Since the vast majority of patients with atherosclerotic RAS have essential hypertension, it is not surprising that intervention to eliminate the stenosis results in a very low cure rate for hypertension. A significant number of patients, however, do obtain better control of their hypertension after stenting, sometimes with a reduced need for medication. A meta-analysis of 14 articles and 678 patients showed a cure of hypertension in 20% and an improvement in hypertension control in 49%.¹ In light of these low percentages, consideration of intervention for hypertension alone is usually limited to patients who fail medical treatment with a three-drug regimen.²

Preservation of renal function

Since the medical treatment of hypertension continues to improve, the emphasis for treatment is shifting to patients whose lesions place them at risk for renal failure. Because atherosclerosis is an ongoing disease, RAS often worsens over time and, if left untreated, can result in irreversible cortical thinning and a concomitant decrease in renal size. This may not be important if the contralateral renal artery and kidney are normal, but may be of paramount importance if the contralateral kidney is compromised. One study of 215 consecutive patients who underwent stenting for ostial RAS reported that serum creatinine decreased during the 1-year follow-up in 52% of patients.³ In the meta-analysis of 14 articles cited earlier, renal function improved in 30% and stabilized in 38% of patients.¹ While no criteria have been proved to predict which patients will benefit most from intervention, there is weak evidence that a positive response to intervention is more likely when the RAS is bilateral or affects a functionally solitary kidney and when renal impairment is mild.⁴

Screening tests

Several non-invasive tests are available to screen at-risk patients for the presence of RAS.⁵ No one test is

best for all patients. Magnetic resonance angiography (MRA) gives a good anatomic depiction of the proximal renal arteries and the abdominal aorta, which is information that can be quite helpful with planning the stent procedure itself. Unfortunately, MRA is expensive and not good at visualizing the distal main renal artery and branches. Computed tomographic angiography (CTA) can yield excellent anatomic information about the aorta, the renal arteries, and the kidneys, but it too is expensive. More importantly, CTA requires the intravenous injection of a relatively large bolus of iodinated contrast material, making its use in patients with renal insufficiency problematic. Doppler ultrasound is a less expensive method for imaging the main renal arteries and detecting velocity shifts that are indicative of stenosis. Ultrasound can also determine the intrarenal arterial resistive index. A high resistive index is indicative of advanced kidney disease and may be predictive of a poor response to intervention.⁶ For these reasons, ultrasound may be the most cost-effective screening tool. Ultrasound studies, however, are operator dependent and often cannot be performed on obese patients or when interposed bowel gas is present. Renal scintigraphy utilizes a more physiologic approach than the other examinations, as there is a delayed and diminished uptake of the radioisotope in a kidney affected by RAS. This test can be quite helpful in uncovering unilateral RAS in an otherwise normal kidney, as is often the case in fibrous disease, and can be predictive of a positive antihypertensive response to angioplasty. It is of less usefulness in bilateral RAS or in the presence of kidney disease.

Patient preparation

Once a decision has been made to pursue angiographic evaluation and possible intervention, appropriate laboratory tests (such as serum creatinine, blood urea nitrogen, international normalized ratio [INR], and complete blood count with platelets) should be obtained and the abnormalities addressed. Ideally, the INR should be less than 1.5 and the platelet count greater than 50 000. Not surprisingly, many of these patients already have an element of underlying renal insufficiency. It is well known that the use of iodinated contrast material can result in nephrotoxicity, especially in patients with pre-existing renal insufficiency and diabetes mellitus. The single best precaution to reduce the incidence of contrast nephropathy is to ensure that the patient is well hydrated. This can be accomplished by the intravenous administration of

normal saline at a rate of 1 ml/kg/h for 12 hours before and after the procedure. There is some inconclusive evidence that hydration with sodium bicarbonate, beginning 1 hour before the procedure and continuing for 6 hours after, may offer better protection than hydration with normal saline. The presumed mechanism is that the formation of free radicals is reduced in an alkaline environment, helping to protect the kidney from oxidant injury.⁷ Similarly, oral administration of the antioxidant acetylcysteine has been promoted to reduce the incidence of contrast-induced nephrotoxicity.⁸ This can be given in three 600 mg doses, one the evening prior to the procedure, another the morning of the procedure, and the last in the evening after the procedure.

Contrast materials

It is important that a low-osmolar, non-ionic iodinated contrast material be used for angiography instead of a high-osmolar one, since the latter has clearly been shown to be more nephrotoxic. Iodixanol, a non-ionic dimer that is nearly isotonic, may be the least toxic of the low-osmolar agents. Because the risk of contrast nephropathy increases as dose increases, it is essential to use the smallest amount of contrast material possible.⁷ One method to accomplish this is to substitute carbon dioxide for iodinated contrast material when possible. Carbon dioxide has no nephrotoxicity and can be used safely in the arterial system below the level of the diaphragm.⁹ Although the image resolution obtained with carbon dioxide is typically inferior to that obtained with iodinated contrast material, it may be quite adequate for part or all of the procedure (Figure 14.1). One disadvantage of carbon dioxide is that it is less dense than blood; as a result, it can layer in the ventral aspect of the abdominal aorta and not sufficiently visualize the more dorsally located renal arteries. Gadolinium-containing contrast agents have also been used as an alternative to iodinated contrast agent. While initially not thought to be nephrotoxic, they have since been found to have an infrequent association with nephrogenic systemic fibrosis in patients with renal insufficiency.¹⁰

Procedural details

The large majority of renal artery lesions can be approached from a femoral arterial entry. On occasion, a brachial artery approach may be necessary when



Figure 14.1 This aortogram was performed with carbon dioxide. Although the resolution is inferior to that typically observed with liquid iodinated contrast material, the proximal left renal artery stenosis is clearly depicted.

there is marked inferior angulation of the renal artery in relation to the aorta or when there is significant occlusive or aneurysmal disease of the infrarenal aorta or iliac arteries. After vascular access into the femoral or brachial artery has been gained, a pigtail catheter with calibration markers is advanced into the visceral segment of the abdominal aorta. An initial abdominal aortogram is obtained to demonstrate the renal arterial anatomy and to assist in determining the correct size of balloon or stent (Figure 14.2A). It is paramount that the ostium of the renal artery be clearly displayed, and it may be necessary to repeat the aortogram at several different angles to accomplish this. In patients with renal insufficiency, the load of iodinated contrast material can be significantly reduced if these initial aortograms are performed with carbon dioxide. Once the correct angulation for display of the ostium has been determined using carbon dioxide injections, a single aortogram with iodinated contrast can be performed if better resolution is needed.

After the presence of a significant renal arterial lesion (typically greater than 60%) has been confirmed and its dimensions defined, the pigtail catheter is replaced with a guiding catheter shaped so that its tip can be aimed at the renal artery ostium. A small caliber wire with a soft angled tip is advanced through the catheter and carefully maneuvered across the stenosis. Great care is taken with the wire tip not to cause an intimal dissection or atheromatous embolization from a plaque. If the stenosis is particularly tight, some operators will choose to perform predilation

with a small caliber balloon (2.5–3.5 mm diameter) in order to facilitate as atraumatic a passage of the balloon-mounted stent as possible.

Several factors are considered in the selection of the stent to be used. A balloon-mounted stent is definitely preferable to a self-expanding stent, since the former can be placed with considerably greater precision. These balloon-mounted stents are generally composed of stainless steel or an alloy. The length of the stent should be selected so that the proximal end extends 1–2 mm into the aortic lumen and the distal end extends 1–2 mm beyond the lesion. For typical atherosclerotic lesions, the stent lengths range from 10 to 20 mm. Longer lesions may require two overlapping stents since it can be difficult to negotiate a stent longer than 20 mm from the aorta into the renal artery. The diameter of the balloon onto which the stent is mounted should be the same as the diameter of the normal renal artery beyond the atherosclerotic lesion, exclusive of any post-stenotic dilatation.

The selected stent/balloon combination is advanced through the guiding catheter over the small caliber wire and then carefully positioned across the lesion. An injection of contrast material is made through the guiding catheter to determine the exact relation of the stent to the lesion and the ostium (Figure 14.2B). If necessary, the position of the stent is adjusted until it is in the optimum location. The balloon is then inflated in order to deploy the stent (Figure 14.2C). A pressure gauge is used to ensure that the pressure does not exceed the manufacturer's recommendation, thus avoiding balloon rupture. The balloon is deflated and removed, leaving the guidewire in place in case further intervention is needed (Figure 14.2D). Follow-up angiography is performed by injection of a small amount of contrast material through the guiding catheter (Figure 14.2E). If the diameter of the stent appears too small, it is possible to expand it to a larger diameter by dilating it with a slightly larger balloon. If a portion of the lesion is uncovered, a second stent can be placed. Once a good result is confirmed by angiography, the wire can be withdrawn. Some operators prefer to use pressure measurements to determine whether a result is satisfactory. The mean pressure gradient from the distal renal artery to the aorta should be less than 10 mmHg.

Some modifications to this basic technique are being explored. A promising one is the use of one of the embolic protection devices that have already been approved for use in the carotid arteries. There are two basic varieties, distal filtering devices and distal occlusion devices. The distal filtering devices come in

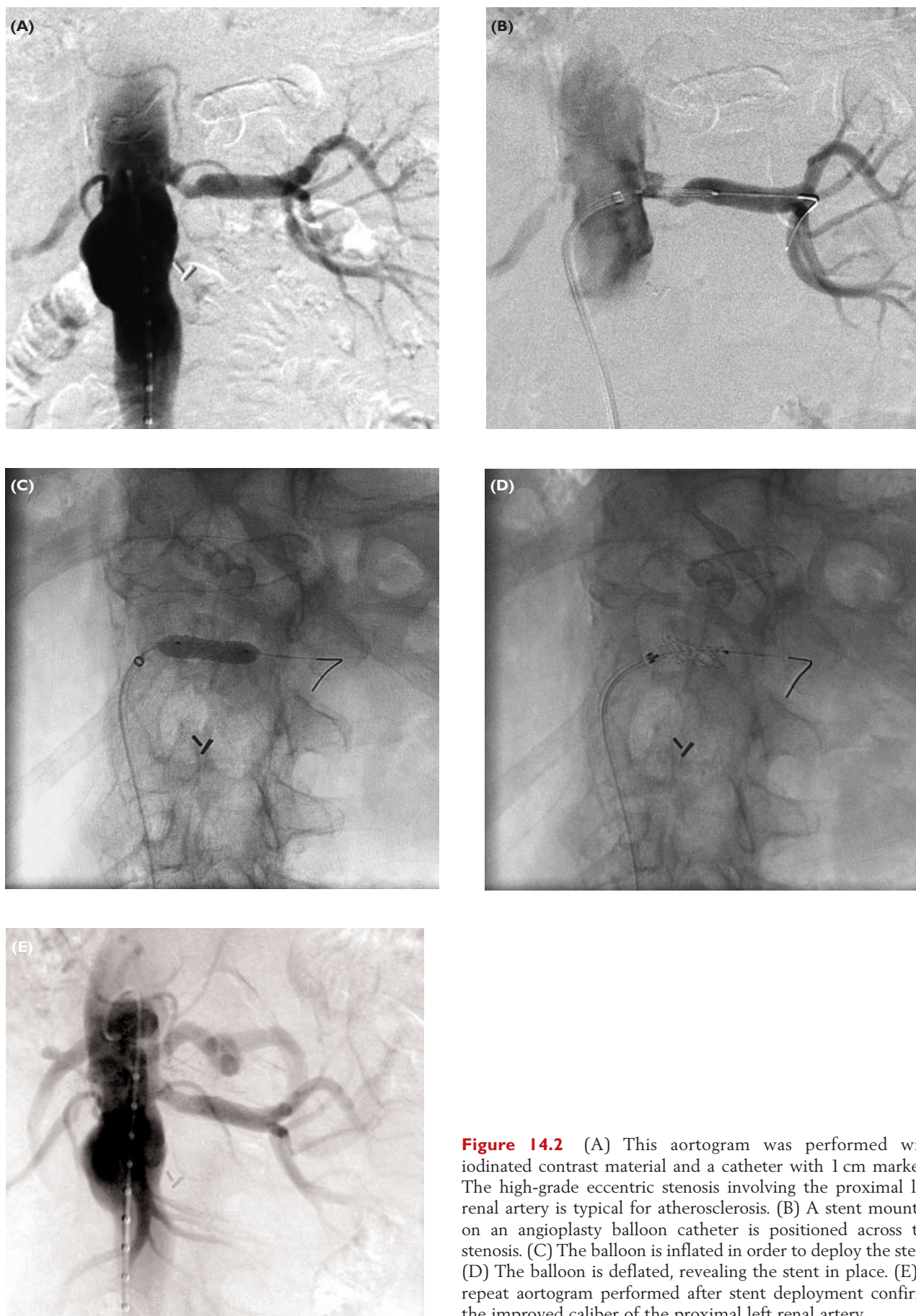


Figure 14.2 (A) This aortogram was performed with iodinated contrast material and a catheter with 1 cm markers. The high-grade eccentric stenosis involving the proximal left renal artery is typical for atherosclerosis. (B) A stent mounted on an angioplasty balloon catheter is positioned across the stenosis. (C) The balloon is inflated in order to deploy the stent. (D) The balloon is deflated, revealing the stent in place. (E) A repeat aortogram performed after stent deployment confirms the improved caliber of the proximal left renal artery.

various designs but basically consist of a cone-like filter at the end of a small caliber wire. The distal occlusion devices, on the other hand, have a soft, compliant balloon near the end of the small caliber wire. The distal occlusion balloon is inflated just before the stent is deployed; any embolic material that results from the stent deployment is then aspirated before the distal occlusion balloon is deflated and removed.

There will no doubt also be advances in stent technology. Drug-eluting stents, similar to those currently used in the coronary arteries, may prove useful in reducing the myointimal hyperplasia that is responsible for development of stenoses that sometimes occur within or at the end of a stent. Another possible future avenue for eliminating intrastent stenoses may be the use of stents covered with graft material, similar to those being used in the iliac and femoral arteries. To date, neither drug-eluting stents nor graft-covered stents are approved for use in renal arteries, and neither has undergone a clinic trial to prove any advantage over bare metal stents.

Complications

The mean incidence of complications from renal artery stenting is 14%.² Complications that can occur at the renal artery site include distal embolization of thrombus or plaque contents into renal artery branches, dissection of the renal artery resulting in flow reduction and possible occlusion of one or more branches, or severe retroperitoneal hemorrhage secondary to interruption of the arterial wall by the balloon expansion or to perforation of the renal capsule by the guidewire. Complications that can occur at the vascular entry site include hematoma, pseudoaneurysm, arteriovenous fistula, dissection, and thrombosis.

Restenosis

Surveillance for restenosis is probably best accomplished with ultrasound, since the presence of a metallic stent compromises CTA and renders MRA ineffectual. The rate of restenosis after stenting has been demonstrated by meta-analysis to be 17%.¹ Stenoses that occur within the stent or at the end of the stent are usually caused by myointimal hyperplasia and, in most cases, can be treated with re-intervention, often by balloon angioplasty alone.¹¹ Since myointimal hyperplasia is promoted by platelet deposition, most operators will place their patients on a several month course of antiplatelet therapy, such as 75 mg of clopidogrel

and 81 mg of aspirin daily, in order to minimize the occurrence of stent-related stenosis or thrombosis.

INTERVENTION FOR FIBROMUSCULAR DYSPLASIA: BALLOON ANGIOPLASTY

Fibromuscular dysplasia (FMD) of the renal arteries tends to present at a younger age than atherosclerosis (typically under 50 years) and more commonly in women. There are several forms of FMD and the classification is based on the arterial layer or layers involved.¹²

Medial fibroplasia is by far the most common type and accounts for approximately 70% of cases of FMD. In this disorder, there are segments of fibrous thickening of the media of the arterial wall that alternate with segments of thinning of both the media and the internal elastic membrane. This results in an angiographic appearance of alternating segments of stenosis and aneurysm, often referred to as a 'string of beads' (Figure 14.3A). As opposed to atherosclerosis which affects the ostium and proximal aspect of the main renal artery, medial fibroplasia affects the mid and distal aspects, and can even extend to involve the proximal branches. It can be unilateral or bilateral and, depending on the degree of stenosis, it can be an asymptomatic incidental finding or it can result in hypertension. It rarely causes renal insufficiency.

Of the less frequently occurring varieties of FMD, perimedial fibroplasia is the most common, accounting for approximately 15% of fibrous lesions. It involves the outer half of the media and the subadventitia. On angiography, this lesion may also appear as a 'string of beads', but the beads are smaller and more irregular than in medial fibroplasia. Also, perimedial fibroplasia is often associated with a network of fine collateral vessels, whereas medial fibroplasia is not. The other types of FMD (intimal fibroplasia, medial hyperplasia, and periarterial hyperplasia) are quite uncommon and difficult to distinguish angiographically with a high degree of certainty.

When renal artery FMD results in hypertension, balloon angioplasty alone is usually appropriate. A cure or significant improvement in hypertension control can be expected in approximately three out of four patients.¹³ The procedure is much the same as described above for stenting for atherosclerotic lesions with the exception that no stent is mounted on the balloon (Figure 14.3B). The balloon inflation fractures the fibrotic stenoses but does not alter the areas of dilatation (Figure 14.3C). These persistent areas of dilatation are of no clinical consequence. Stenting has no established role in the treatment of FMD

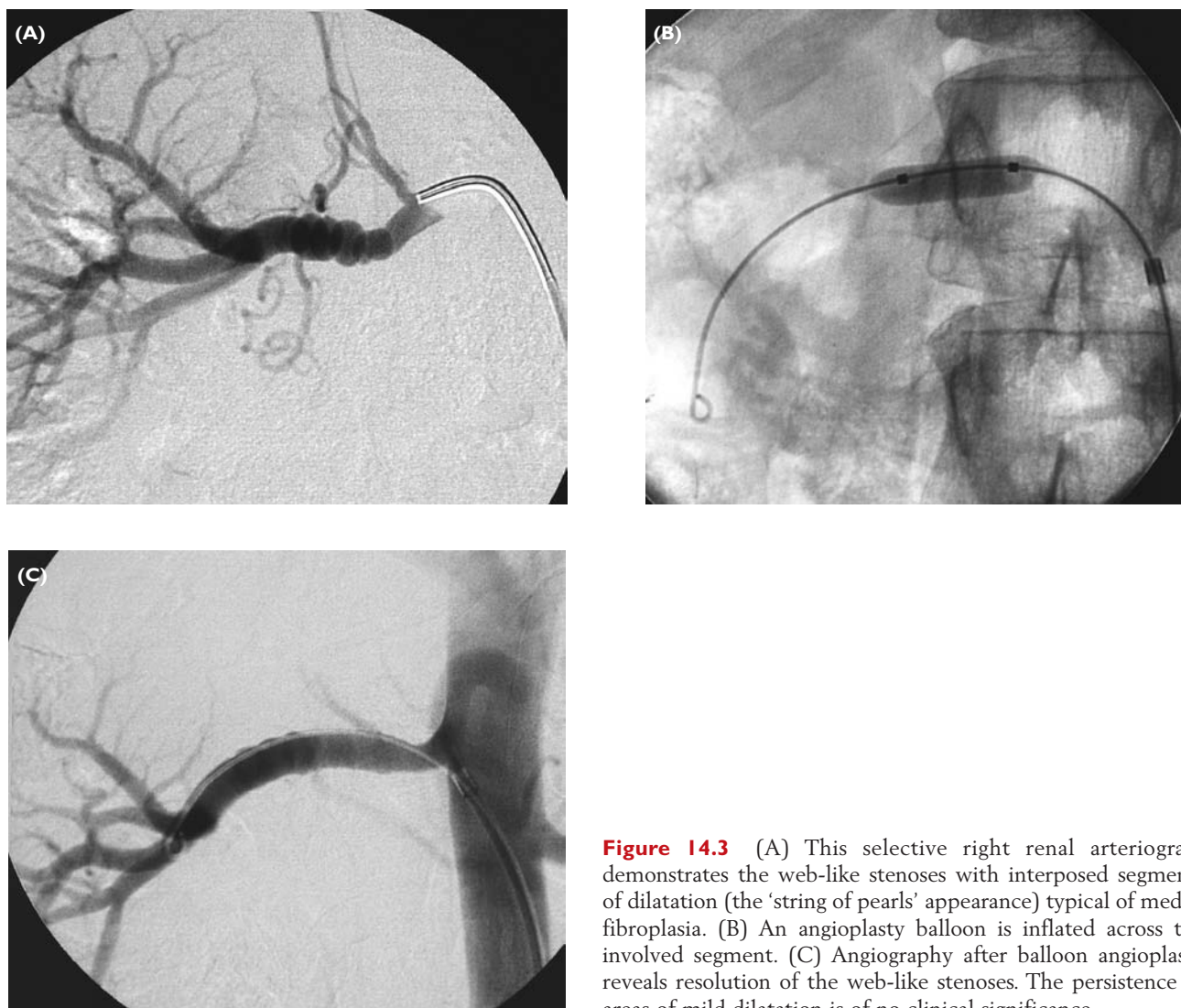


Figure 14.3 (A) This selective right renal arteriogram demonstrates the web-like stenoses with interposed segments of dilatation (the 'string of pearls' appearance) typical of medial fibroplasia. (B) An angioplasty balloon is inflated across the involved segment. (C) Angiography after balloon angioplasty reveals resolution of the web-like stenoses. The persistence of areas of mild dilatation is of no clinical significance.

and is reserved for the few instances where a significant dissection has occurred from the angioplasty procedure.

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15 Renal transplantation

Stuart M Flechner and Alain Duclos

The first successful kidney transplant was performed between identical twins in 1954, ushering in over 50 years of development and innovation in the field of solid organ and bone marrow transplantation. Kidney transplantation is now considered the preferred method of renal replacement therapy worldwide, due to ever improving outcomes producing a better quality of life, and a prolongation of survival compared with dialysis.¹ The major reasons leading to improved outcomes are more potent yet selective immunosuppression, better surgical techniques, and better prophylaxis and treatment of infections. In the US, there are currently about 325 000 patients receiving renal replacement therapy, with an incident rate of about 330 per million population.² For the year 2005, there were 16 477 kidney transplants performed, 9914 from deceased donors and 6563 from live donors.³ The use of kidneys from unrelated live donors such as spouses, friends, and altruistic individuals yields outcomes similar to those from biologic relatives, and is the fastest growing donor source. The success of this procedure has created a gap of over 65 000 between the number of waiting patients and available organs.⁴ Currently, 1- and 5-year kidney graft survival ranges are 89–95% and 66–80%, respectively, depending on donor source.⁵

PREOPERATIVE EVALUATION OF THE RECIPIENT

There are few absolute contraindications to renal transplant. These include active infection or cancer, severe cardiovascular disease, and metabolic diseases likely to recur (oxalosis or cystinosis) in the new kidney. Patients with a life expectancy of less than 4–5 years are probably better served by remaining on dialysis. Physiologic age rather than chronologic age is considered a more important predictor of outcome.⁶ Outside the medical realm, psychosocial and environmental factors should also be considered, as the ability to follow a complex medical regimen is essential to maintain long-term graft function. Prior to transplant it is important to identify correctable conditions that

may increase morbidity and diminish outcomes after the transplant.⁷

URINARY TRACT EVALUATION

The native urinary tract will resume its normal function after a successful kidney transplant, even after decades of renal failure. Potential recipients who produce urine, are asymptomatic, and do not have a prior history of urologic interventions, do not need extensive evaluation. An upper tract ultrasound and urine culture are sufficient. Urinary cytology should be performed in patients at risk for urothelial neoplasia. In males, prostate specific antigen (PSA) and digital rectal examination (DRE) should be performed according to standard recommendations. Patients with past or current urologic symptoms (hematuria, stones, recurrent infections, or incontinence), previous urologic interventions, or neurogenic bladder should be fully investigated. Further evaluation includes upper tract and pelvic imaging, cystoscopy, cytology, and urine culture. For certain cases a urodynamic study and/or voiding cystogram should be performed. A computed tomography (CT) scan with intravenous contrast can be safely performed in dialyzed patients. Magnetic resonance imaging (MRI) can be used for those patients not on dialysis.

UPPER TRACT PATHOLOGY

Less than 10% of recipients need their native kidneys removed prior to transplant. The kidneys contribute to erythropoietin and vitamin D3 production, some urine output, and potassium excretion. The indications for native nephrectomy include heavy proteinuria (>10 g/day), intractable hypertension, and persistent hematuria. In addition, lesions that may harbor malignant growth (enhancing masses, filling defects, complex or very large cysts) or potential sources of infection (chronic hydronephrosis, high-grade reflux, stones, abscesses) should be removed. Large polycystic kidneys may also require nephrectomy for symptoms,

infection, or size. In most cases, nephrectomy or nephroureterectomy can be performed laparoscopically with decreased morbidity.^{8,9}

LOWER TRACT PATHOLOGY

Dialyzed patients with anuria develop small capacity bladders with lower compliance, but the majority of these defunctionalized bladders resume normal function once urine volume is restored.¹⁰ A few defunctionalized bladders may not recover due to fibrosis and scarring, as a result of prior surgery, radiation, tuberculosis, posterior urethral valve, or meningomyelocele. In these unusual cases, bladder augmentation, a continent neobladder, or urinary diversion may be needed. Major reconstructions should have healed and be functioning before transplantation. Lower tract procedures such as transurethral resection of the prostate, bladder neck incision, or urethral stricture repair performed on a dry urinary tract will usually fail from further scarring. Such procedures should only be performed if the urine output is normal. They should also be avoided for the first 3 months post-transplant when immunosuppression is maximal and healing slower.

OPERATIVE PROCEDURE FOR TRANSPLANT RECIPIENTS

General principles

It is important to begin the procedure with the placement of a central venous line for fluids, drugs, and monitoring. Preoperative broad-spectrum antibiotics are given. After induction of anesthesia, a 20–22 Fr Foley catheter is placed. The bladder is then filled by gravity to about 200 ml with normal saline containing 50 000 units of bacitracin, and the catheter is clamped. For smaller defunctionalized bladders the catheter is placed, but filled later in the procedure using sterile technique to help identify the bladder. During the transplant an internal double J ureteral stent is universally employed. The operative side is shaved and prepped, and the transplant is performed. Once the surgery is completed, a retroperitoneal closed suction drain is commonly placed. Wound closure is generally performed in two layers, with the external oblique fascia closed with interrupted No. 1 non-absorbable sutures and the deeper layer (fascia and muscle of internal oblique and transversalis) closed with No. 1 running monofilament polydioxane. Skin closure is performed

with vertical mattress with 3-0 nylon sutures that will remain in place for 2–3 weeks. In patients with body mass index (BMI) larger than 30 kg/m² a closed suction subcutaneous drain is placed in an effort to reduce seroma formation. The Foley catheter is usually removed on postoperative days 4–5, but may be extended for difficult urinary tract reconstructions. Drains are generally removed when draining less than 40 ml/day. The ureteral stent is removed 4–6 weeks after surgery with flexible cystoscopy.

Gibson incision

A right or left lower quadrant Gibson incision allows creation of a potential space in the iliac fossa for the new kidney, and access to the iliac vessels, bladder, and ureter (Figure 15.1). If needed, it can be extended upward and an ipsilateral nephrectomy can be performed through the same incision. With the patient in the supine position an incision is made one finger breadth above the symphysis pubis and two finger breadths medial to the anterior superior iliac spine, which can be tailored to meet the needs of individual patients. After incising the subcutaneous tissue, the external oblique aponeurosis is incised in the direction of the wound carefully avoiding the sheath of the rectus abdominis. The internal oblique and transversalis fascias and muscles are then incised using electrocautery, thus exposing the retroperitoneal space. The inferior epigastric artery and vein are ligated between silk ties and divided as they pass near the posterior aspect of the rectus. In women, the round ligament is ligated between silk ties and divided, whereas in men the spermatic cord can generally be mobilized and retracted out of the way. Next, the peritoneum is gently swept medially off the iliac vessels; use of a stick sponge is helpful.

Dissection of the iliac fossa

Dissection of the iliac fossa is shown in Figure 15.2. A self-retaining retractor is placed at this time; the abdominal Bookwalter (Codman) is preferred. Care must be taken to avoid compression of the ilio-psoas musculature, since the femoral nerve trunk lies just beneath, and compression can lead to postoperative neuropathy. Liberal padding with sponges is equally important to prevent injury to the lateral femoral cutaneous nerve, and the peritoneum. Correct placement of the retractor should allow visualization of the common

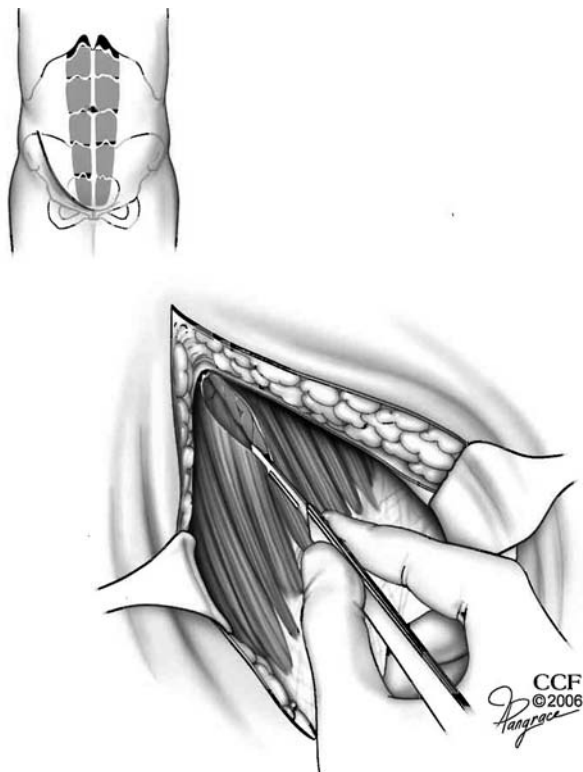


Figure 15.1 Gibson incision. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

iliac artery at the cephalad end of the field, the external iliac artery and vein at the caudal end of the field, as well as the native ureter. The lymphoareolar tissues surrounding the iliac vessels are then carefully dissected with electrocautery. Visible lymphatic trunks should be ligated and divided, in an effort to prevent lymphocele formation. Dissection should expose the minimal amount (6–8 cm) of arterial and venous length required for anastomosis to the renal vessels. On occasion, as in a deep android pelvis, the internal iliac vein may require ligation and division to help elevate the external iliac vein. However, when the donor renal vessels are short, damaged, or become difficult to suture in a particular recipient, it is prudent to replace or extend them. This can be done using a vessel from the recipient (hypogastric artery, saphenous vein, etc.) or by using a third-party graft from a prior deceased donor.¹¹

RENAL TRANSPLANTATION

End-to-side anastomosis of renal artery and vein. The running quadrant technique is used. The vascular anastomoses set the position of the kidney, which eventually lies on the psoas (Figure 15.3A). It is important not to place the anastomoses too distal on the iliac vessels, which may

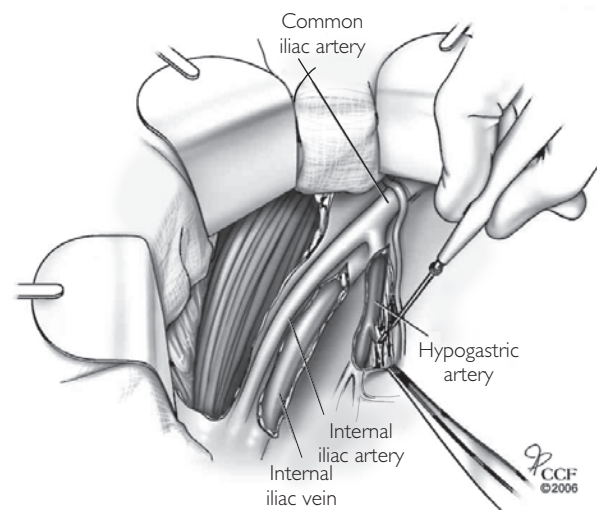


Figure 15.2 Dissection of the iliac fossa. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

make wound closure more difficult and result in compression of the kidney on the iliacs. The venous anastomosis is usually performed first by placing a Satinsky clamp on the external iliac vein, cutting a venotomy as long as the width of the renal vein, and irrigating the vein with heparin solution (Figure 15.3B). The running quadrant technique using two double-armed 5-0 prolene sutures is preferred. The anastomosis starts at the corners and ends in the middle, as each side is done separately. A small nerve hook can be helpful to elevate vessel edges during suturing. The same technique, using two double-armed 6-0 prolene sutures is used for a single renal artery. A Cooley C clamp is used for isolating a segment of external iliac artery, and a 4.5–5 mm aortic punch is helpful for creating a smooth rounded arteriotomy. Vascular anastomosis partially completed. When the venous anastomosis is completed, a small bulldog clamp is placed on the renal vein and the Satinsky is removed to test for leaks, which can be repaired prior to revascularizing the kidney. Similarly, a bulldog clamp is applied to the renal artery and the Cooley clamp removed after the arterial anastomosis is completed. The kidney is finally revascularized by removing the bulldog clamps first from the vein and then the artery.

End-to-end anastomosis using internal iliac artery

Sometimes, the internal iliac artery is an optimal size match to the renal artery and is used in an end-to-end anastomosis (Figure 15.4). This requires careful dissection of the internal iliac artery and good control of the

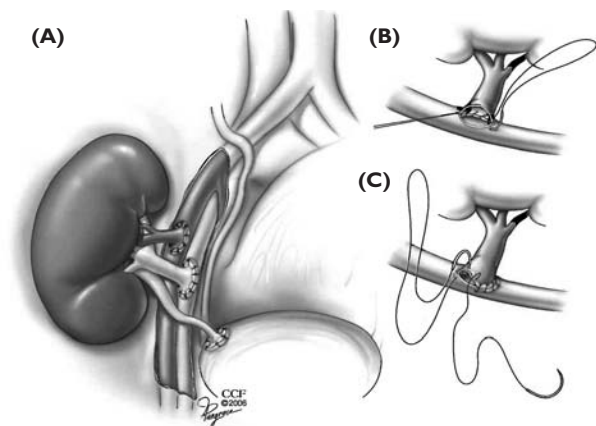


Figure 15.3 (A), (B), (C). Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

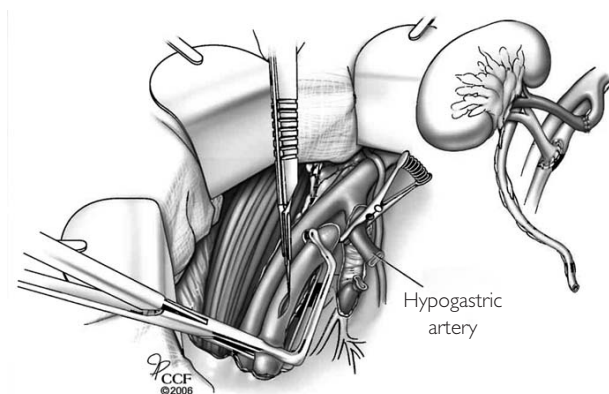


Figure 15.4 End-to-end anastomosis using internal iliac artery. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

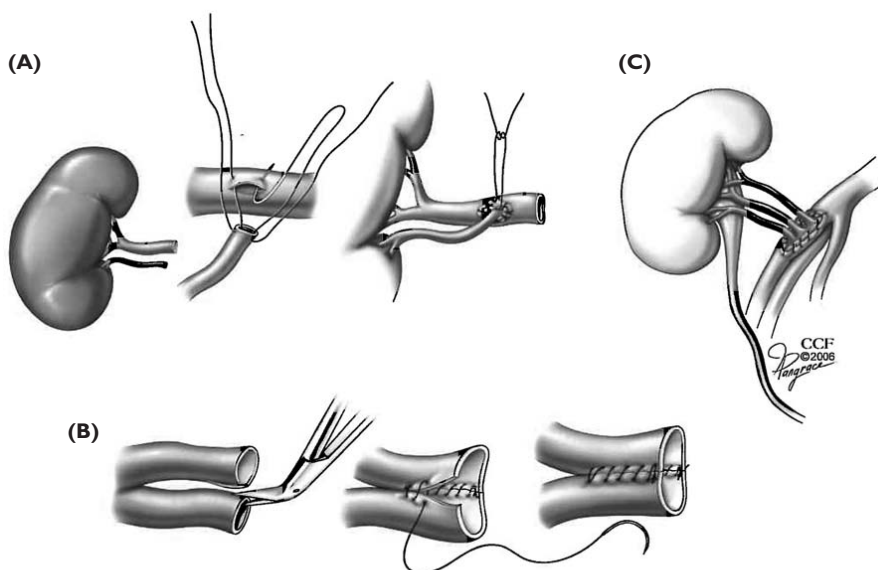


Figure 15.5 (A), (B), (C). Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

distal stump with non-absorbable suture. This technique avoids extensive dissection of the external iliac artery, but is more often useful in younger patients since the hypogastric artery is frequently involved with atherosclerosis in the elderly and diabetics. The anastomosis can be performed using the running quadrant technique with 6-0 prolene; or at times an interrupted suture technique. The renal and hypogastric arteries should be trimmed to avoid excess length and kinking.

Vascular techniques for multiple renal arteries

When two or more arteries are encountered in the donor kidney, several options are available for revascularization. Arteries that are wide apart (>3–4 cm) can

be anastomosed separately to the recipient external iliac artery, but may prolong ischemia time. Another option is to use ex vivo techniques for reconstruction at the back table while the kidney is still on ice, which optimizes exposure, illumination, and magnification. An end-to-side implantation of the smaller to the larger artery using fine 7-0 prolene suture with an interrupted technique can be performed (Figure 15.5A). Once the anastomosis is completed it should be tested for competence with heparinized saline, as further repair will be easier at this time. When two donor renal arteries of approximately equal size are encountered, another option is to perform a conjoint anastomosis (Figure 15.5B). On the back table, both arteries can be spatulated with a Potts scissors, and joined together using 7-0 prolene suture with a running technique. For deceased donor kidneys a patch of donor aorta can be preserved that contains multiple

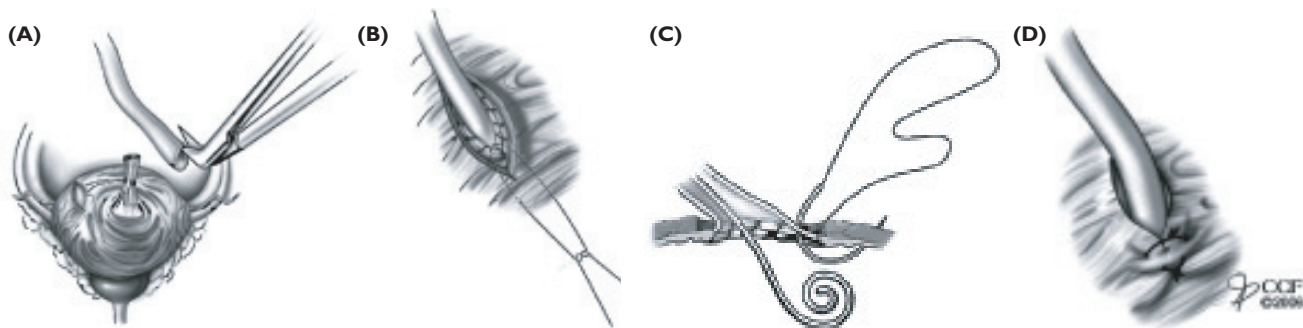


Figure 15.6 (A), (B), (C), (D). Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

renal arteries. This can then be directly anastomosed to the common or external iliac artery using a running 6-0 prolene suture (Figure 15.5C).

Extra vesical ureteral reimplantation using a stent

A U-stitch is placed to secure the ureter to the bladder. The most commonly performed ureteral implantation is a tunneled extravesical anastomosis (Lich-Grégoire). The transplant ureter is tailored to reach the bladder without tension while carefully preserving the periureteral blood supply, and then spatulated for 1 cm (Figure 15.6A). With the bladder full a bubble of mucosa is developed by gently cutting away detrusor muscle both sharply and with the electrocautery. The bubble of mucosa is then incised at its caudal aspect and the ureter is anchored only to the mucosa (Figure 15.6B). The anastomosis is then constructed with either an interrupted 5-0 vicryl or a running 5-0 polydioxanone suture on either side. Before completing the anastomosis, an advancement or U-stitch of 3-0 vicryl is placed at the apex of the anastomosis well in the detrusor tunnel. A double-J ureteral stent is placed, first up to the kidney then down to the bladder before the anastomosis is completed (Figure 15.6C). The final step of the ureteral anastomosis is the closure of the detrusor muscle in order to create an anti-refluxing tunnel (Figure 15.6D). It may also prevent formation of bladder diverticulum. Using several interrupted sutures of 3-0 vicryl, both detrusor muscle and perivesical tissue are loosely reapproximated over the deeper ureter.

Transplantation into an ileal conduit

If a potential recipient has no functional bladder, then the transplanted kidney may be drained by an ileal conduit (Figure 15.7). The conduit may be pre-existing, but if

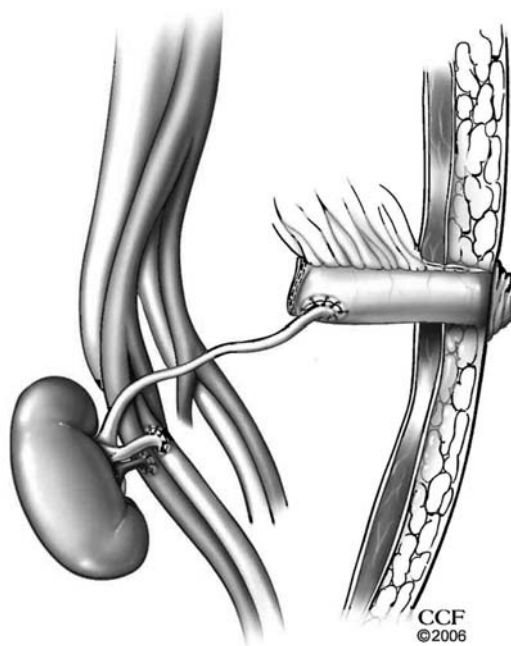


Figure 15.7 Transplantation into an ileal conduit. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

specifically created for the transplant, it should be given at least 6–8 weeks to heal prior to transplant surgery. In addition, the conduit should be placed into an extraperitoneal pocket. In such cases, the transplant kidney is deliberately placed upside-down, for a more direct route between the kidney and the conduit. The ureteroileal anastomosis should be stented for several weeks.

Adult dual kidney transplantation: ipsilateral technique

The drastic shortage of kidneys for transplant has created novel opportunities to expand the organ supply.¹² It is possible to use both kidneys from an older donor

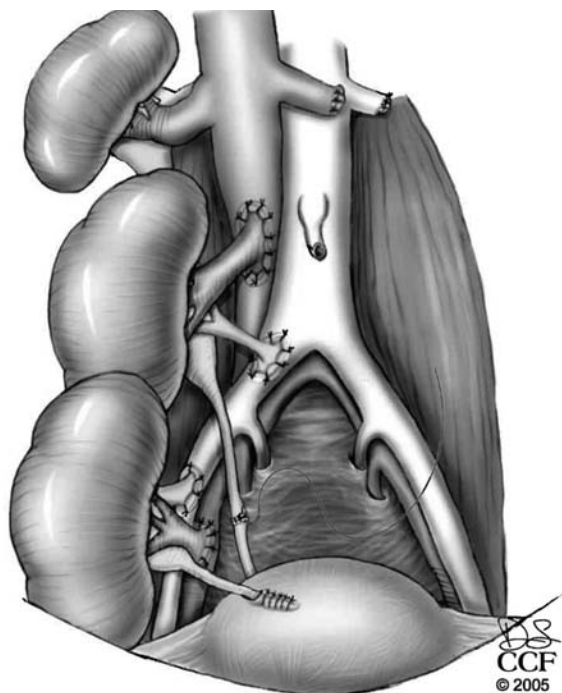


Figure 15.8 Adult dual transplantation. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

(over age 65) or for ischemically damaged kidneys where one would not provide a sufficient nephron dose (Figure 15.8). We prefer an ipsilateral approach to place both kidneys by extending the Gibson incision upward, while still remaining retroperitoneal. This incision exposes the inferior vena cava, aorta, iliac vessels, native ureter, and bladder. The right kidney is placed first, to the inferior vena cava and common iliac artery, both with end-to-side anastomoses of running prolene. If the right renal artery is short, it can be anastomosed to the lower aorta in order to create a tension-free anastomosis. This kidney is revascularized first, in order to permit re-clamping of the iliac vessels below, while maintaining blood supply to the upper kidney. The lower renal unit is the left kidney, and is placed in the usual manner in the iliac fossa. The venous anastomosis between the renal vein and the external iliac vein is constructed end-to-side with 5-0 running prolene suture. The renal artery is anastomosed end-to-side to the external iliac artery with running 6-0 prolene suture.

Adult dual kidney transplantation

The two ureters are reimplanted separately into one bladder, or one to one bladder and one to the native

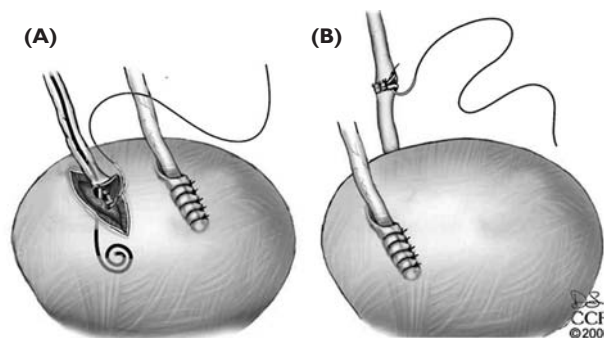


Figure 15.9 (A), (B). Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

ureter. When a duplicated collecting system is encountered with one kidney, the ureters have a common sheath and blood supply. They can be reimplanted by conjoining their ends to form one ostia for attachment to the bladder using the extravesical Lich technique. Each ureter should be spatulated on its avascular side for 1–1.5 cm. The two ureters are then joined at their apex with absorbable 5-0 running suture. A separate stent can be left in each ureter. The disadvantage to this technique is that the anastomosis will be disrupted should one of the two ureters undergo necrosis. In addition, if done with two kidneys, the entire renal function may be affected by necrosis or stricture in one ureter.

In adult dual kidney transplants the ureters are separate and have their own individual blood supply. It is safer to reimplant each ureter separately with its own tunnel and stent (Figure 15.9A). Both bubbles should be prepared before the mucosa is opened, as developing a bubble of mucosa with the bladder decompressed is very difficult. An obvious advantage to this approach is that each ureter maintains its own blood supply; if one ureter becomes necrotic or strictures the other ureter will remain unaffected. A potential drawback to this technique is that the ureteral length for the upper renal unit may be excessive, and result in ischemia or tension on the anastomosis. Our preferred alternative is to join the upper kidney's ureter to the native ureter in an end-to-end fashion, while performing a standard tunneled and stented extravesical ureteral implantation for the lower renal unit (Figure 15.9B). The ureteroureterostomy is generally performed in a running quadrant technique using two double-armed 5-0 polydioxanone sutures, and a stent is placed antegrade into the bladder. Stent placement can be facilitated with an open-ended ureteral catheter and guide wire, if difficult to negotiate. Ligation of the native ureter has not caused morbidity in our experience, but some degree of hydronephrosis can be observed.

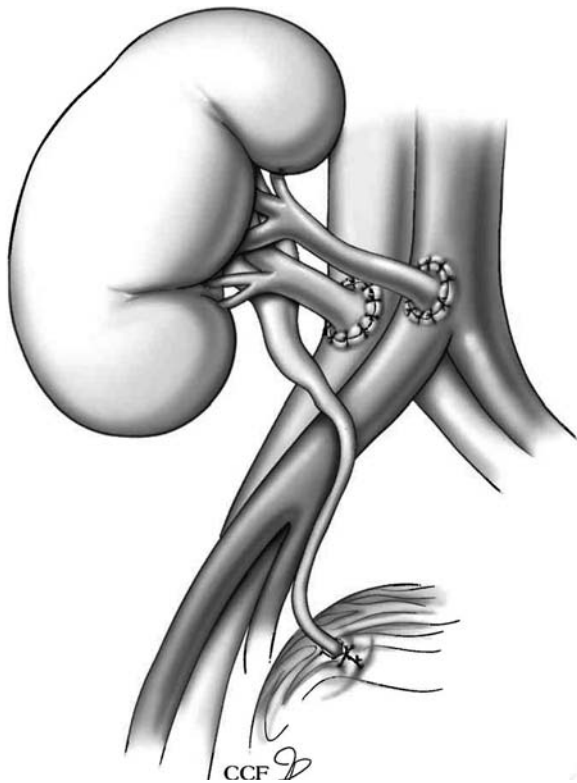


Figure 15.10 Adult kidney into small child. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

Adult kidney into small child

When adult kidneys (often from parents) are transplanted into small children the iliac vessels may not be of sufficient size to deliver adequate blood flow to the allograft. In addition, the pediatric iliac fossa may not provide a large enough space for the kidney. In such cases, the lower aorta or the common iliac artery is used for end-to-side arterial anastomosis with the renal artery, while the inferior vena cava is used for the renal vein (Figure 15.10). Children 15 kg or less may be approached through a midline intraperitoneal incision, whereas older children will do well with a conventional retroperitoneal approach. In very small children it is also important to keep the child's blood volume expanded when the kidney is revascularized, as blood pressure may drop as the new kidney fills with a significant proportion of the child's available blood volume.

Pediatric donor en bloc transplantation

Transplantation of both kidneys from very young donors (under age 5) is advisable for a number of reasons. While small kidneys grow in an adult environment, if they do not provide a sufficient renal mass

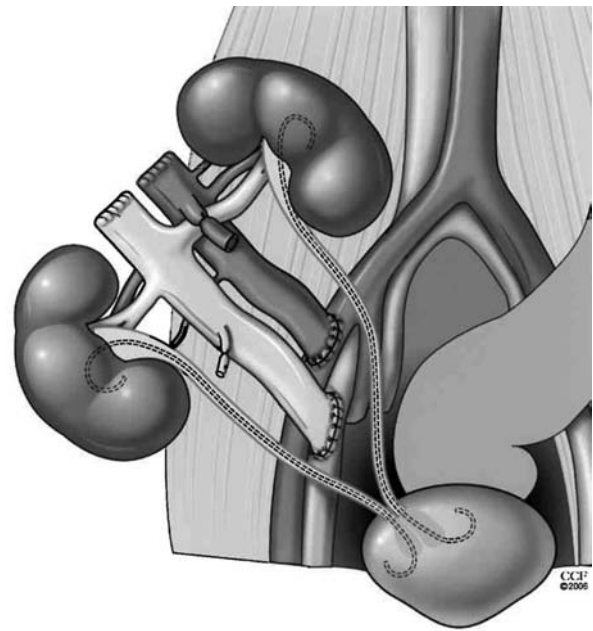


Figure 15.11 Pediatric donor en bloc transportation. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

(nephron dose) for the adult recipient they may not produce an adequate long-term glomerular filtration rate (GFR). This occurs because such kidneys are subject to injury from hyperfiltration, which may lead to proteinuria and glomerulosclerosis. In addition, the renal vessels of small kidneys are delicate, and subject to laceration, dissection, torsion, and ultimately thrombosis. Therefore, transplanting them en bloc with the donor aorta and vena cava provides the best opportunity for technical success (Figure 15.11). Prior to transplantation the small pediatric kidney should be carefully inspected for injury and torsion; however, overzealous dissection of the hilum may unintentionally injure these delicate organs. Also, there must be sufficient length (at least 4–5 cm) of inferior vena cava and aorta to allow for tension-free anastomosis to the iliac vessels. About 1–2 cm is needed above the renal vessels for closure of the cephalad end of both the donor aorta and vena cava.

Preparation of the pediatric en bloc kidneys begins on the posterior side by ligating all the lumbar branches on the inferior vena cava and aorta with 6-0 prolene. It is helpful to place a vascular sound across these vessels for support. Then, the cephalad openings of both inferior vena cava and aorta are closed with running 6-0 prolene suture. Once completed the vessels should be tested with heparinized saline to exclude vascular leaks. For implantation, the most critical part of the procedure is to lay the kidneys on the psoas muscle perpendicular to the iliac vessels. This provides support

for the kidneys and prevents the kidneys from dropping deeper in the pelvis. The donor inferior vena cava is anastomosed to the external iliac vein with a running 6-0 prolene using the quadrant technique. Similarly, the donor aorta is anastomosed to the common or external iliac artery using 6-0 prolene running suture. Alternatively, if size matched in younger recipients the donor aorta can be anastomosed to the hypogastric artery in an end-to-end fashion. For ureteral implantation our preference is to perform two separate stented anastomoses. In this way, a ureteral complication in one kidney will not compromise the other. Finally, a nephropexy to prevent twisting around the axis of the renal vessels is done by suturing some excess perirenal fat from the upper and lower poles of the kidney to the psoas muscle with chromic suture.

LIVING DONOR EVALUATION

Potential living kidney donors undergo a thorough medical and surgical history and physical examination. It is particularly important to identify cardiovascular disease, diabetes, hypertension, obesity, infections, neoplasia, and urologic/renal disorders that may compromise renal function or increase the operative risk for this elective procedure. In addition, it is important to identify infectious agents that can be transmitted to the recipient. Testing includes a chest X-ray, electrocardiogram (if indicated, cardiac stress test), blood chemistry and serology, and urine analysis and culture. GFR and urinary protein excretion are essential. We now use a CT angiogram to assess renal and vascular anatomy. In a few cases with multiple arteries, a catheter angiogram is done.

The decision regarding which kidney to remove is made after considering advantages/disadvantages for both the donor and recipient. In principle, the best kidney should always be left with the donor. When kidneys are equal, the left kidney is preferred because of its longer and often sturdier renal vein. If a kidney has multiple renal arteries, the kidney with a single artery is selected. In young fertile females, considering that physiologic hydronephrosis of the right kidney occurs during pregnancy, it may be prudent to use their right kidney for transplant.

OPERATIVE PROCEDURE FOR LIVING KIDNEY DONORS

Today, laparoscopic intraperitoneal donor nephrectomy has supplanted open donor nephrectomy in

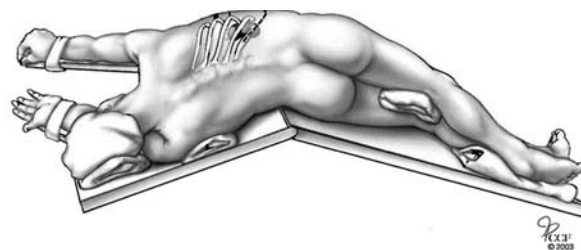


Figure 15.12 Donor nephrectomy flank position. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

many centers due to reports of reduced pain and shorter recovery time, bolstered by internet advertising.¹³ There is little doubt that this approach is less morbid for large donors (>100 kg) who require large incisions. However, proper preoperative counseling can allay many donor concerns, and the principle of 'leaving the best kidney with the donor' should apply regardless of which method is used to remove the donated kidney. An open surgical donor nephrectomy is indicated in a number of cases, particularly when the right kidney is to be removed, which has a short and at times thin-walled renal vein. In addition, it is advantageous when the recipient is large and maximal renal vessel length is needed. In such cases a short renal vein or three or more renal arteries may compromise the recipient operation. The open surgical approach permits the safe removal of a cuff of donor vena cava, which extends vessel length and also allows for a thicker edge for suture placement in the recipient. The least morbid incision for open donor nephrectomy is the rib sparing extraperitoneal flank approach first described by Turner-Warwick.¹⁴ This technique eliminates the psychologic concern of the donor regarding the loss of a rib, and minimizes the risks of incisional hernia and neuropraxia.

After induction of general anesthesia a Foley catheter is inserted, and the patient is placed in the flank position (Figure 15.12). The table is flexed, the kidney rest is used to support the down side, and the patient is finally placed in slight Trendelenburg position. A roll under the down side axilla will help prevent brachial plexus injuries. Donors are well hydrated in the perioperative period with normal saline, and mannitol is infused both at the initiation of surgery and at the time of renal hilar manipulation in order to keep urine output at about 150 ml/h.

For most donors an incision of 8–10 cm is made directly over the 12th rib, slightly longer in bigger

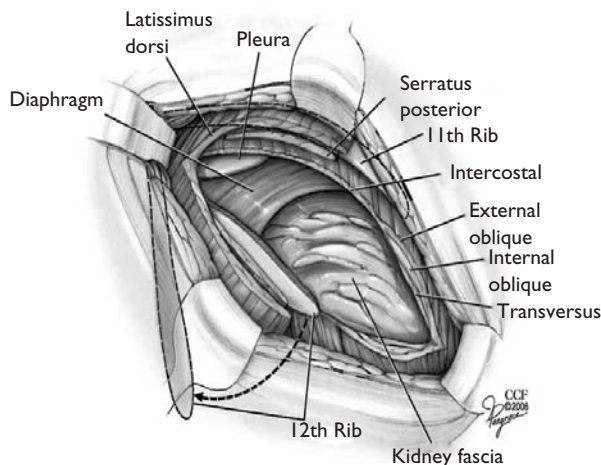


Figure 15.13 Donor nephrectomy flank incision. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

patients (Figure 15.13). The incision continues directly above the rib avoiding the neurovascular bundle below the rib. The retroperitoneum is entered at the tip of the 12th rib, and the intercostal muscles are incised at the superior margin of the 12th rib. Some diaphragm is incised to displace the pleura upward. After incising the costo-vertebral ligament, the rib easily articulates downward as a self-retaining retractor is placed. The retroperitoneum is developed with blunt and sharp dissection around Gerota's fascia, and the peritoneum is swept medially. At completion of the nephrectomy, the rib returns to its normal position, and a two-layer closure is done with running No. 1 polydioxanone suture. First, a lower layer of serratus and intercostal muscle just above the rib is constructed, which continues medially with the internal oblique and transversus muscle. Then an upper layer of latissimus dorsi continuing medially with the external oblique is created. The skin and subcutaneous tissues can be closed with a running vicryl suture.

After removing Gerota's fascia around the kidney, the ureter is identified and followed down to the level of the iliac vessels, but not divided at this time (Figure 15.14A). It is important to maintain the blood supply to the ureter by preserving the fibroareolar tissue around it. The kidney is further mobilized sparing the adrenal gland. The renal vein and the renal artery are dissected away from the hilum (where branching occurs), and surrounded with soft vessel loops (Figure 15.14B). In some cases, additional arterial length can be gained by dissecting lateral and behind the vena cava. After final confirmation that the recipient is ready for transplant, the ureter is divided at the level of the iliac vessels. Additional volume, mannitol, and

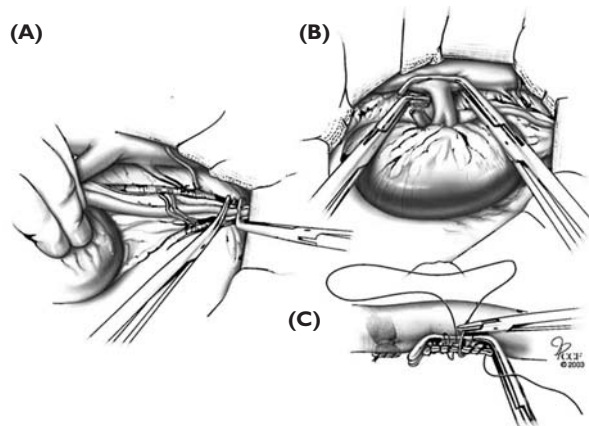


Figure 15.14 Right open donor nephrectomy with cuff on vena cava. (A), (B), (C). Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

furosemide can be given at this point to ensure a diuresis in the donor kidney. Any remaining retroperitoneal tissues are divided, so the kidney is only attached by the renal artery and vein. The renal artery is controlled with a fine right angle clamp and divided leaving a few millimeters of length above the clamp (Figure 15.14C). Warm ischemia begins at this point until the kidney is removed and flushed with a cold perfusate on the back table. The vena cava is partially occluded with an angled Satinsky clamp centered over the renal vein. The renal vein is divided including a 2–3 mm cuff of vena cava, and the kidney is removed from the patient. The artery is then doubly secured with 0 silk tie and ligature. The vena cava is oversewn with running 5-0 polypropylene suture.

The initial exposure and steps for the left side are similar to that of the right side. After the retroperitoneal space is entered, the peritoneum is swept medially off of Gerota's fascia across to the aorta, while carefully packing off the spleen. The gonadal vein is identified and tissue between the gonadal vein and the ureter is preserved (Figure 15.15). Tracing up the gonadal vein is useful to localize the renal vein. The kidney is then mobilized from Gerota's fascia and the adrenal gland is gently separated from the upper pole. Again, the renal artery and vein are dissected away from the hilum, and surrounded with soft vessel loops. The renal vein is completely dissected free of its areolar tissue to the right side of the aorta. Complete renal vein mobility requires division and ligation of the gonadal vein, the adrenal vein, and one or more lumbar veins with silk ties. The renal artery is dissected to its origin at the aorta. When the recipient is ready for transplant, the ureter is divided and the stump is ligated in the pelvis at the level of the

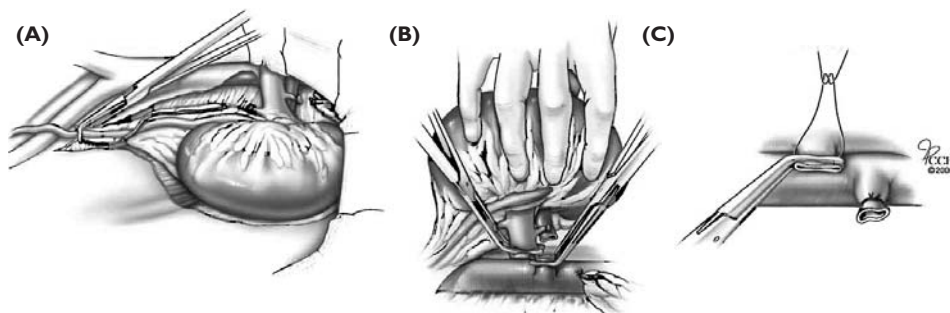


Figure 15.15 Left open donor nephrectomy. (A), (B), (C). Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

iliac vessels. Before kidney removal a diuresis from the ureter is ensured. The renal artery is clamped as closely as possible to the aorta, and divided with scissors leaving a few millimeters above the clamp. Warm ischemia time starts at this point until the kidney is flushed with a cold perfusate on the back table. The renal vein is controlled with a right angle clamp over the medial aspect of the aorta and divided. The kidney is removed. The renal artery is doubly secured with 0 silk tie and ligature. The vein can be secured with 0 silk sutures or closed with a running 5-0 polypropylene suture. Wound closure is completed as for the right side.

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16 Open surgical management of ureteropelvic junction obstruction

Carlos R Estrada and Alan B Retik

INTRODUCTION

The preservation of renal function is one of the most important responsibilities of the urologist. Ureteropelvic junction obstruction (UPJO) can lead to progressive renal compromise, and therefore it is imperative that the urologist recognize if, when, and how to intervene. If repair of the UPJO is indicated, a pyeloplasty provides the urologist with one of the most gratifying surgical experiences in all of urology, and provides the patient with a highly successful and definitive repair. The reported success rates of open pyeloplasty range from 83 to 100%.¹⁻⁸ Repair cannot recover lost renal function, but it may prevent further deterioration and optimize overall renal function. Recently, minimally invasive approaches to repairing UPJO such as endopyelotomy,⁹ laparoscopic pyeloplasty,¹⁰ and robotic assisted laparoscopic pyeloplasty^{11,12} have gained experience and favor, but the open surgical repair of UPJO remains the gold standard to which all other modalities are compared.

DIAGNOSIS

The diagnosis of UPJO is most commonly entertained following routine obstetric ultrasonography during fetal life and is confirmed in the neonatal period. Antenatal hydronephrosis affects 1–5% of all pregnancies but its clinical significance remains unclear.¹³⁻¹⁶ It is known that the majority of antenatally detected cases of hydronephrosis are likely to resolve over time without surgical intervention,¹⁷ however, more severe cases are more likely to be associated with significant urologic pathology, including UPJO.¹⁸ Ultimately, it is the responsibility of the urologist to determine which cases represent true UPJO that imperils renal function. For children in whom the diagnosis is not made in the neonatal period, the classic signs and symptoms of UPJO include flank and/or abdominal pain, vomiting, fever, urinary tract infection, hematuria, and renal calculi.^{19,20}

The radiologic evaluation of the patient with a suspected UPJO usually begins with an ultrasound. The



Figure 16.1 Ultrasonographic appearance of a ureteropelvic junction obstruction. The communication of the dilated calyces with the renal pelvis is demonstrated.

distended renal pelvis often assumes a triangular configuration, and when viewed in the proper plane the renal pelvis is seen to communicate with the dilated renal calyces (Figure 16.1). If renal damage has been sustained, the parenchyma may be dysplastic and appear echogenic on ultrasonography. This finding, however, is not an absolute indicator of impaired renal function or of obstruction, both of which must be assessed with a nuclear renal scan. Technetium-99m mercaptoacetyltriglycine (MAG-3) is the radiopharmaceutical agent of choice for dynamic renal scintigraphy in the setting of suspected obstruction.²¹ This agent is excreted by renal tubular secretion and provides a measure of each kidney's contribution to overall glomerular filtration as well as a measure of each kidney's ability to excrete the agent.²² To obtain the most accurate information, the MAG-3 renal scan should be performed in a standardized fashion. The variables that should be considered for standardization include the amount of radiopharmaceutical agent injected, patient hydration status, imaging time, dose of furosemide administered, and the time at which furosemide is given.^{23,24}

The MAG-3 renal scan provides two objective measurements. First, the half-time ($T_{1/2}$) quantifies the time

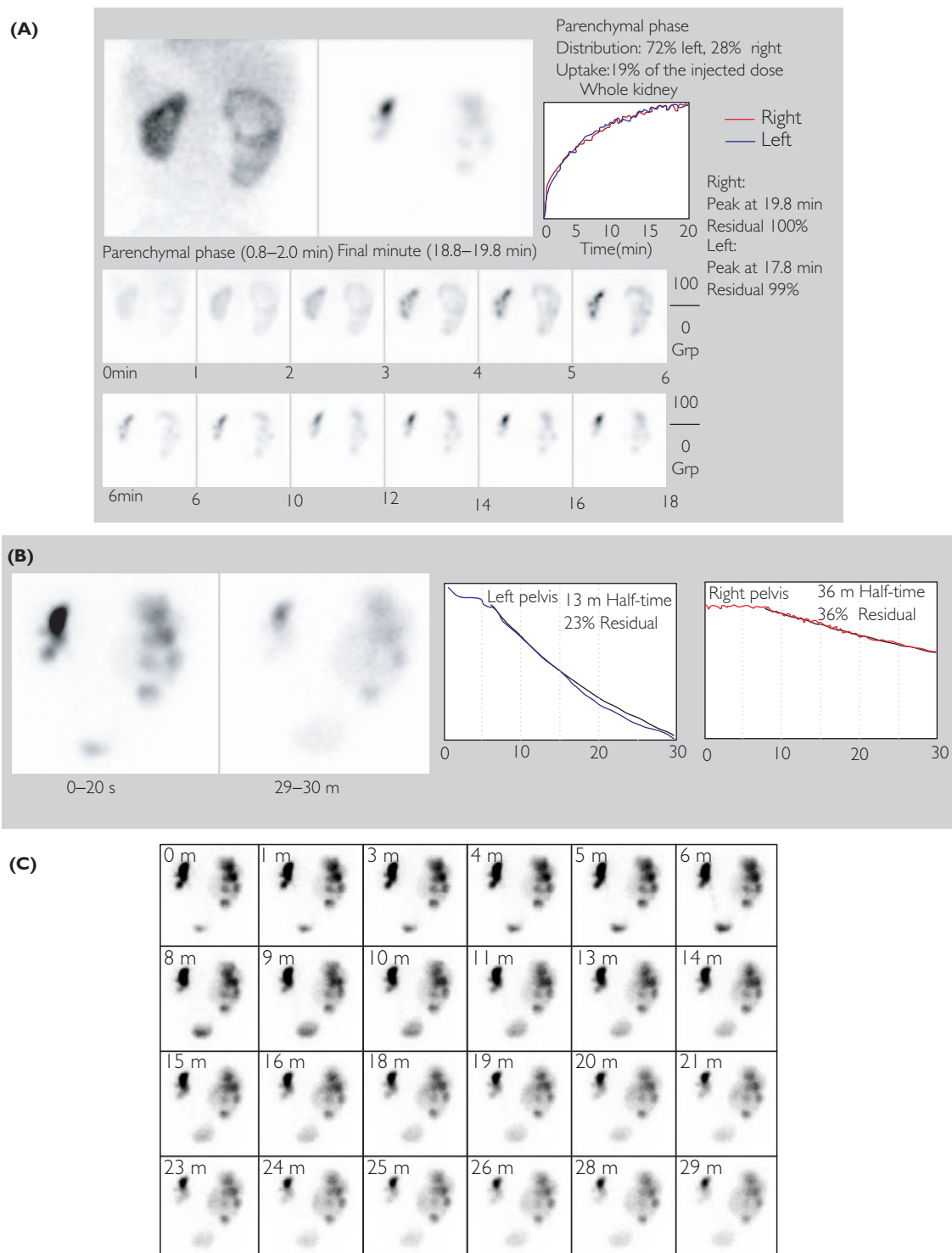


Figure 16.2 (A) The parenchymal phase of the MAG-3 renal scan demonstrates significant renal function impairment of the right kidney. The large hydronephrotic kidney is well visualized in the parenchymal phase. (B) Following furosemide administration, the half-life ($T_{1/2}$) is calculated. This study demonstrates a significant (>20 minutes) delayed $T_{1/2}$ on the right. (C) Static images obtained during the post-furosemide excretion phase demonstrating significant retention of the radiopharmaceutical on the right side.

in minutes that it takes for the kidney to clear half of its maximal counts (Figure 16.2). In general, a $T_{1/2}$ less than 10 minutes indicates non-obstruction, while a $T_{1/2}$ greater than 20 minutes indicates obstruction. A $T_{1/2}$

between 10 and 20 minutes is considered equivocal. Second, the differential renal function quantifies the contribution of each kidney to overall glomerular filtration. A differential function of less than 40% in the

setting of hydronephrosis may be considered significant impairment. The decision to proceed with surgical repair is dependent on the synthesis of the available data, i.e. the ultrasonographic appearance of the kidney, the $T_{1/2}$, and the differential function. In rare cases, these tests are equivocal and the Whitaker test can assist in the definitive diagnosis.²⁵ This test measures the pressure differential between the renal pelvis and the bladder during constant renal pelvic perfusion maintained via a needle placed percutaneously in the kidney. A pressure differential of greater than 20 cmH₂O is indicative of obstruction.

Although these diagnostic modalities can provide useful information, each has its limitations and imperfections. The natural history of UPJO remains unclear, and the urologist is charged with utilizing the available studies to best ascertain whether surgical repair is indicated. We hope that future refinements to these modalities and/or new diagnostic tests developed in the laboratory will assist the urologist with this critical decision.

OPEN SURGICAL REPAIR

The modern open surgical management of UPJO has evolved substantially from the first pyeloplasty performed by Trendelenburg in 1886.²⁶ We utilize the dismembered pyeloplasty originally described by Anderson and Hynes in 1949 for repair of almost all cases of UPJO. The other type of repair in the modern urologist's armamentarium is the flap type of pyeloplasty. These include the Y-V flap pyeloplasty described in 1937 by Foley, the Culp and deWeerd spiral flap introduced in 1951, and the vertical flap described by Scardino and Prince in 1953. The flap types are reserved for the rare cases of high ureteral insertion and/or limited length of ureter that are not amenable to the dismembered pyeloplasty. The remainder of this chapter addresses the Anderson-Hynes dismembered pyeloplasty.

Radiologic studies should be available for viewing in the operating room, allowing the urologist to confirm the side of surgery and re-review the objective data available. The patient should be given prophylactic intravenous antibiotics prior to incision. We do not routinely perform cystoscopy and retrograde pyelogram at the time of pyeloplasty, but some authors have reported a benefit in doing so.²⁷ Prior to positioning, a Foley catheter is placed using sterile technique.

We prefer the classical flank incision for access to the kidney, although anterior subcostal or dorsal lumbotomy approaches are viable options. For the flank approach, the patient should be placed in the lateral

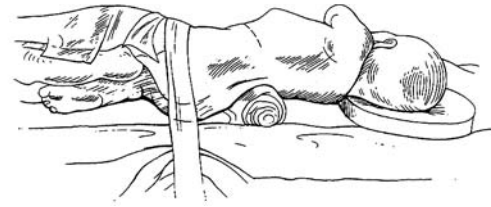


Figure 16.3 The lateral decubitus position for a left flank approach. The space between the ribs and the iliac crest is extended in children with a rolled towel or gel pad.

decubitus position with the lower leg flexed at the knee and the upper leg extended with padding placed between them (Figure 16.3). In this position, the flank is extended to increase the space between the iliac crest and the lower margin of the rib cage.²⁰ This is facilitated by the placement of rolled towels or gel pads in the infant patient, or by raising the kidney bar and flexing the table in the older child. An axillary roll is used under the dependent axilla to prevent brachial plexus injury. The patient is taped in this position with one or two pieces of tape that extend from one side of the table to the other over the hip. Care must be taken that the tape is not applied too tightly, but tightly enough so that it can hold the patient in place if the operating table is tilted laterally during the operation. The ipsilateral arm and hand are draped over padding and are also secured in place with tape. The patient is prepared and draped in the usual sterile fashion. The subsequent steps in the Anderson-Hynes dismembered pyeloplasty via a lateral flank approach are as follows.

- (1) A 4–6 cm subcostal incision is made below the tip of the 12th rib that extends from the posterior border of the latissimus dorsi to the lateral border of the rectus abdominis anteriorly.
- (2) The three muscle layers, the external oblique, internal oblique, and transversus abdominis, are divided using electrocautery. Care must be taken to sweep the peritoneum medially beneath the transversus abdominis prior to its transection. When encountered, the intercostal neurovascular bundles should be preserved. Alternatively, a muscle splitting technique may be used, where each muscle is separated in the direction of its fibers. Once the muscle layers are divided or separated, Gerota's fascia becomes visible and is opened longitudinally.
- (3) Gentle blunt dissection is used to dissect posteriorly to the level of the psoas muscle, inferiorly to the level of the lower pole of the kidney, and superiorly to isolate the upper pole of the kidney. The renal pelvis is identified and the peritoneum

is bluntly dissected medially. A self-retracting ring retractor (curved Denis-Browne) is placed. For optimal exposure of the UPJ, the lower pole of the kidney may require cephalad retraction.

- (4) The UPJ is identified, surrounded with a vessel loop, and is dissected free from surrounding tissues to prepare it for the subsequent anastomosis. A traction suture is placed on the anterior surface of the ureter just distal to the expected site of ureteral transection. Traction sutures are placed in the renal pelvis on the superior and inferior aspects of the proposed renal pelvic transection (Figure 16.4).
- (5) A diamond-shaped portion of the renal pelvis is excised and traction sutures are also placed on the medial and lateral aspects of the opening. The stenotic segment of ureter is excised, with attention to the use of the previously placed traction suture to ensure minimal handling of the ureter. A feeding tube is advanced in an antegrade fashion to the level of the bladder to prove ureteral patency.
- (6) The ureter is spatulated longitudinally along its lateral aspect using fine straight or Potts tenotomy scissors (Figure 16.5A,B). Care should be taken to not create a spiraled ureteral spatulation, and dissection around the ureters should be limited to that necessary to create a tension-free anastomosis. Medial dissection of the ureter risks its devascularization and therefore imperils a successful UPJ reconstruction.
- (7) The anastomosis is started by suturing the apex of the ureteral spatulation to the most dependent portion of the renal pelvis (Figure 16.5C). We prefer 6-0 or 7-0 polyglactin (Vicryl) for the anastomosis, and it is imperative that absorbable suture material be used to prevent the formation of calculi. All knots are tied on the outside of the anastomosis. As with any other urologic reconstructive surgery, minimal tissue handling must be strictly adhered to. Meticulous attention must be paid to precise placement of sutures, and particular attention paid to the ureteral sutures so that the back wall is not caught. The ureteral lumen can be gently spread with fine forceps to assist in the placement of the ureteral sutures. A feeding tube may be placed intermittently to ensure the patency of the anastomosis.
- (8) The ureteropelvic anastomosis is completed with simple interrupted sutures, and any redundant renal pelvis is closed to itself with a running suture of the same absorbable material (Figure 16.6 and 16.7). Prior to completing the closure

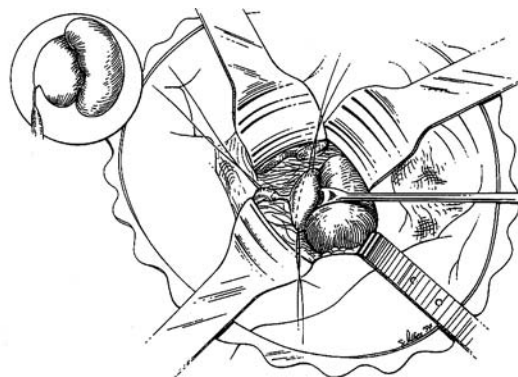


Figure 16.4 Exposure of the UPJ. Traction sutures are placed in the renal pelvis and the ureter to aid in exposure and to delineate the extent of the resection (dashed line).

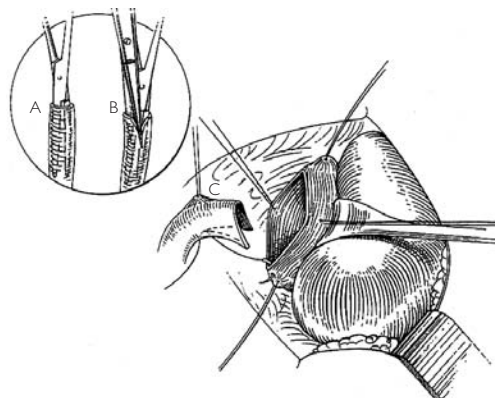


Figure 16.5 (A) and (B) The ureter is spatulated along its lateral border. (C) The anastomosis is started by suturing the apex of the ureteral spatulation to the dependent aspect of the renal pelvis.

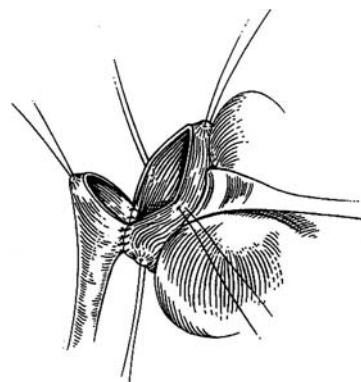


Figure 16.6 The ureter is anastomosed to the renal pelvis with interrupted fine absorbable sutures.

of the renal pelvis, it is irrigated free of blood clots. We reserve the use of nephrostomy tubes and/or indwelling JJ ureteral stents for cases of reoperation or solitary kidney.²⁸

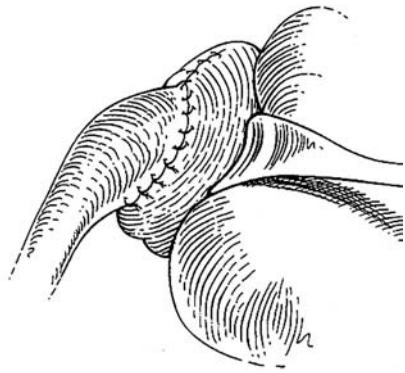


Figure 16.7 Following the ureteropelvic anastomosis, the remaining renal pelvis is closed with a running suture of the same absorbable material.

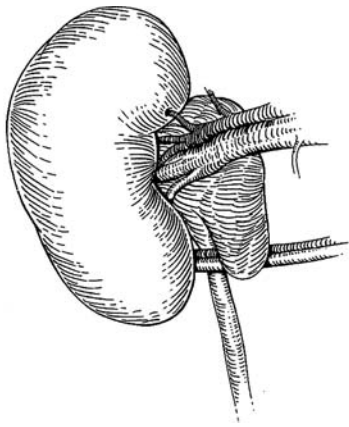


Figure 16.8 The UPJ is draped over the lower pole crossing vessels, creating a UPJO.

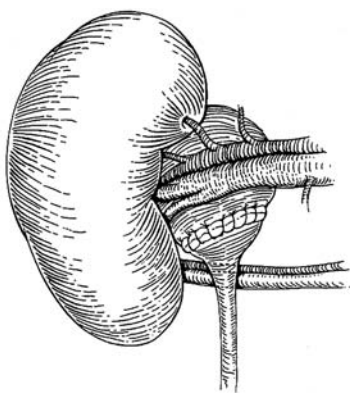


Figure 16.9 The UPJ is transected and transposed to anterior to the lower pole crossing vessels. The UPJ is then reanastomosed using standard dismembered pyeloplasty technique.

- (9) A penrose drain is placed through a separate stab incision inferior to the flank incision. Careful attention is paid to place the drain in the perirenal fossa, but not in direct contact

with the anastomosis. The drain is secured at the skin level with a nylon suture. Extra length of penrose drain may be left in the perirenal fossa that can be withdrawn at the end of closure to ensure that it was not caught with any suture.

- (10) The muscle layers and Scarpa's fascia are closed individually with a running absorbable suture. The skin is reapproximated with a running subcuticular suture using absorbable material, reinforced with Steri-Strips™, and covered with a sterile dressing. Multiple gauzes are placed over the penrose drain and are secured using Montgomery straps. The Foley catheter is left in place.

UPJOs may also occur in duplex renal collecting systems, and in these cases, occur almost exclusively in the lower pole moiety.²⁹ In these cases, the Anderson-Hynes dismembered pyeloplasty may be performed, but another option is the anastomosis of the lower pole renal pelvis to the upper pole ureters in an end-to-side or side-to-side configuration. The ureterotomy in the upper pole ureters should be laterally placed and be at least 1.5 cm in length to allow for adequate lower pole drainage. As with all anastomoses, it should be tension free and without angulation.

In addition to the more common intrinsic obstruction, UPJO may be caused by an obstructing lower pole crossing vessel (Figure 16.8). This type of obstruction frequently results in episodic symptomatology and is most commonly diagnosed in the older child. In these cases, when the dissection of the renal pelvis is completed, the crossing vessels may not appear to be obstructing, and one may be tempted to fix the position of the crossing vessel and the renal pelvis as described by Hellstrom.³⁰ However, it is more advisable to transect the UPJ and transpose it anterior to the crossing vessels to definitively repair the obstructive process. The transposition is readily accomplished following dissection of the lower pole vessels, and traction sutures placed in the renal pelvis and ureters aid in the process. During dissection, it is imperative that any possible blood supply to the ureters from the lower pole crossing vessels is not disrupted. The repair is then performed in the standard Anderson-Hynes dismembered pyeloplasty fashion (Figure 16.9).

UPJO may also be caused by a long stricture or fibrosis from a failed previous pyeloplasty. In these cases, a ureterocalycostomy is well suited for the reconstruction of the UPJ.^{31–34} This procedure is also applicable for proximal ureteral strictures which result in significant hydronephrosis, dilatation of the lower pole calyces, and thinning of the surrounding renal parenchyma (Figure 16.10). Dissection of the

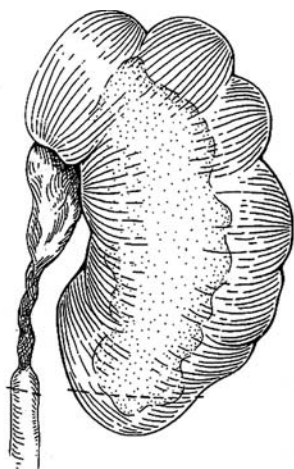


Figure 16.10 Proximal ureteral stricture with resultant hydronephrosis and parenchymal thinning. The dashed lines indicate the locations of ureteral and lower pole transection in preparation for a ureterocalycostomy.

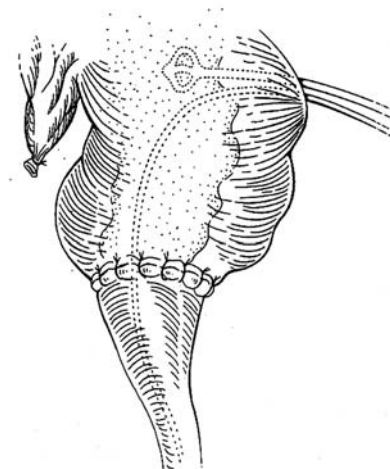


Figure 16.12 The ureterocalycostomy is completed. A nephrostomy tube as well as a ureteral stent are left in place.

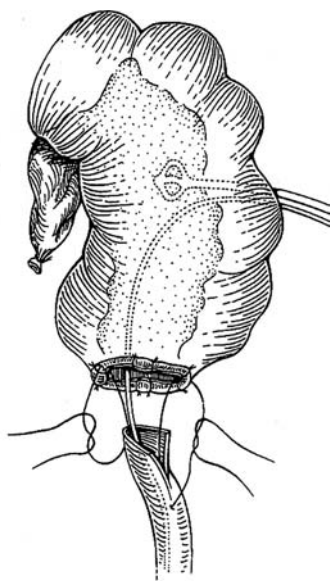


Figure 16.11 Ligation of the renal pelvis. The ureter is spatulated and anastomosed to the most dependent renal calyx. The complete amputation of the renal lower pole is mandatory.

ureter is limited to what is necessary to achieve a tension-free anastomosis. Vascular control is achieved by surrounding the renal artery and vein with vessel loops. The lower pole of the kidney is transected and amputated transversely to allow for a wide ureterocalyceal anastomosis (Figures 16.11 and 16.12). It is critical that a complete amputation of the lower pole be performed. The ureter is spatulated as previously described.

DORSAL LUMBOTOMY

The Anderson-Hynes dismembered pyeloplasty can also be performed via the posterior dorsal lumbotomy.³⁵ This approach is advantageous in that it avoids the muscle incisions of the flank approach and therefore may be less morbid. However, because the incision cannot be extended as much as the flank incision it may limit exposure during difficult dissections or surgical misadventure. For the routine pyeloplasty, however, the dorsal lumbotomy is a reasonable alternative to the more widely utilized flank or anterior abdominal approaches.

The patient is positioned prone with gel rolls or towels placed longitudinally extending from the anterior chest to below the iliac crests. The incision is made in an oblique fashion so as to bisect the angle between the junction of the 12th rib and the spine, and is carried to just above the iliac bone (Figure 16.13). After the subcutaneous fascia is incised, the latissimus dorsi aponeurosis is encountered and is incised in the same direction as the skin incision. Blunt dissection is used along the lateral border of the sacrospinalis muscle until the lumbodorsal fascia is encountered (Figure 16.14). This fascia is also incised in a longitudinal fashion, with care not to injure the iliohypogastric nerve which lies perpendicular to the incision. The retroperitoneal space is then entered, and Gerota's fascia is immediately encountered. A standard dismembered pyeloplasty is performed as previously described. With this approach, the urologist must maintain his/her orientation and recall the medial and lateral positions, which initially appear different from those of the flank approach.

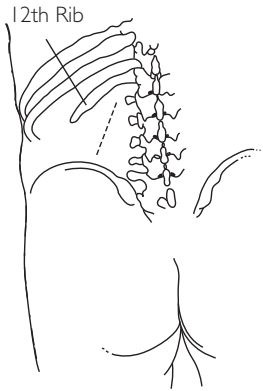


Figure 16.13 The incision for the posterior dorsal lumbotomy approach is demonstrated.

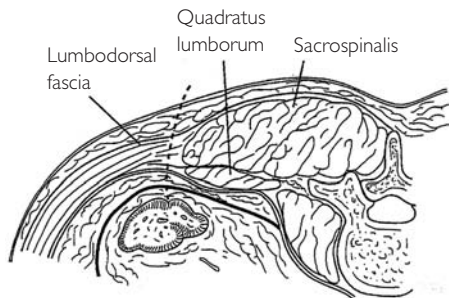


Figure 16.14 The posterior dorsal lumbotomy approach allows direct access to the retroperitoneum. Dissection is carried down lateral to the posterior muscles and the lumbodorsal fascia is incised revealing the underlying Gerota's fascia.

POSTOPERATIVE CARE

The Foley catheter is removed after 24 hours. The output from the penrose drain will dictate its removal, which is usually between 2 and 5 days postoperatively. Alternatively, the patient may be discharged to home with the penrose in place to be removed at a 1 week postoperative visit. Activity is restricted for approximately 3 weeks. Postoperative imaging may include ultrasonography and a functional study, such as the MAG-3 renal scan. It is important to note that the degree of renal pelvic dilatation may appear unchanged for an extended period of time. The functional study should be the same one utilized in the preoperative evaluation. The high success rates associated with the Anderson-Hynes dismembered pyeloplasty should be anticipated if the urologist adheres to thorough preoperative evaluation, is familiar with all of the surgical options, and has uncompromising surgical technique.

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17 Laparoscopic pyeloplasty

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INTRODUCTION

Ureteropelvic junction obstruction (UPJO) is the most common cause of hydronephrosis in neonates. It is likewise not infrequently seen in adult urologic practice and all urologists should be familiar with indications for treatment and basic reconstructive options. Classically, patients may present with flank pain, nausea, vomiting, fever, or hematuria. Additional potential sequelae may include kidney infection, stone formation, and loss of renal function.

The majority of cases of UPJO are congenital in etiology. These may be classified into intrinsic and extrinsic causes. Intrinsic causes may result from remnant valves or mucosal folds or disorientation of smooth muscle fibers at the UPJ. Extrinsic causes may include angulation or high insertion of the ureter, bands, kinks, or crossing vessels (Figure 17.1). Although less common, acquired cases are often more complex to treat resulting from previous failed repair, trauma, stone disease, or instrumentation. While the etiology may exclude patients from some treatment options, laparoscopic pyeloplasty (LP) has been successfully employed in all settings and offers the greatest flexibility while maintaining a minimally invasive approach.

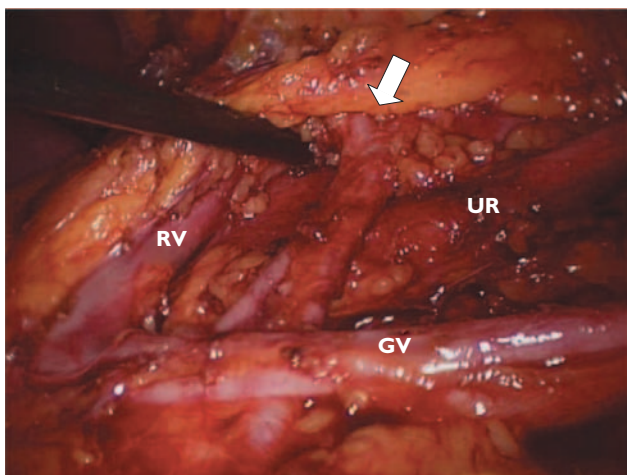


Figure 17.1 Intraoperative photograph demonstrating left-sided ureteropelvic junction obstruction due to lower pole crossing vessels (white arrow). RV, renal vein; GV, gonadal vein; UR, ureter.

EVALUATION

Initial evaluation should begin with a brief history focusing on symptoms and timing. The typical presentation is intermittent flank pain and nausea associated with increased fluid intake or diuretic use. Specifically excessive alcohol intake may trigger symptoms. It is important to elicit any prior history of infection, stone disease, or previous surgery. Physical examination is often completely normal unless the patient is seen during an episode of pain in which they will likely have costovertebral angle tenderness. Laboratory testing should include a serum creatinine and urinalysis with culture when appropriate. Anatomic and functional imaging is necessary to confirm the diagnosis of UPJO. Our preferred initial study is computed tomography (CT) of the abdomen and pelvis utilizing a CT urogram protocol with precontrast, immediate post-contrast, and delayed excretory images. This allows for complete visualization of the size, shape, and relationship of the renal pelvis to ureter and identifies any associated calculi, crossing vessels, or tumors. Radionuclide diuretic renography is often useful to confirm the diagnosis of obstruction, document the degree of obstruction, and measure split renal function. While additional imaging is not required, we do routinely perform a retrograde pyelogram immediately prior to LP to further delineate the anatomy and aid in placement of a ureteral stent (Figure 17.2). In selected cases, a voiding cystourethrogram (VCUG) may be useful to rule out vesicoureteral reflux.

INDICATIONS AND TREATMENT OPTIONS

Indications for treatment of UPJO include symptomatic obstruction (flank or abdominal pain, nausea), recurrent infection, calculi, or progressive loss of renal function. Relative indications include progressive worsening of hydronephrosis or severe obstruction as documented by time-activity curves (half-life [$T_{1/2}$] greater than 20 minutes) on radionuclide diuretic renography. The flexibility of reconstructive techniques available with pyeloplasty allows it to be

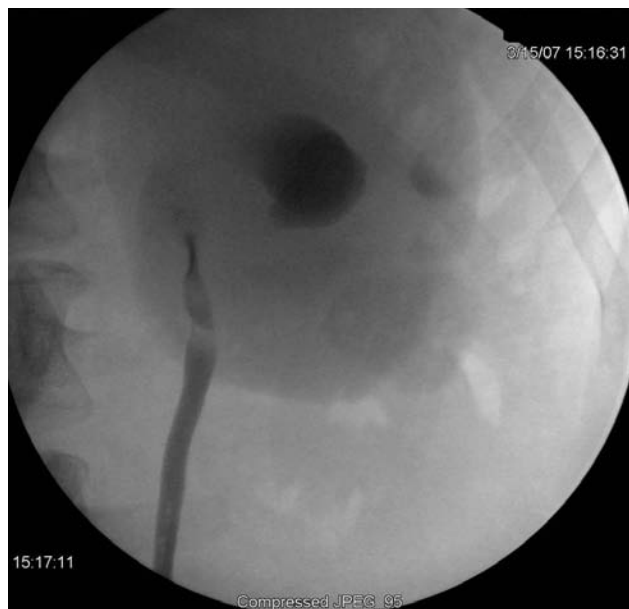


Figure 17.2 Intraoperative retrograde pyelogram obtained at the time of laparoscopic pyeloplasty. Note high insertion of UPJ and large dilated renal pelvis.

employed in nearly all cases of UPJO. The indications for laparoscopic or robot assisted approaches are identical to those for open repair.

Contraindications to pyeloplasty include a small intrarenal pelvis or poor renal function (less than 15% split function) in the presence of a normal contralateral kidney. While technically challenging, secondary UPJO is not a contraindication to laparoscopic or robot assisted LP. In cases of previous abdominal surgery, a retroperitoneal laparoscopic approach may be utilized to avoid intraperitoneal adhesions.

The gold standard treatment for UPJO is open pyeloplasty with historically reproducible success rates greater than 95%.¹⁻⁴ Formal reconstruction also allows the surgeon the greatest flexibility to manage intraoperative findings such as crossing vessels, a large redundant renal pelvis, or high insertion and make appropriate adjustments in the repair. Over the past two decades, alternative techniques have been developed which aim to reduce patient morbidity while attempting to achieve equivalent results. Based on the initial work of Davis in 1943 with 'intubated ureterotomy',⁵ the endopyelotomy was developed and modern series reported reasonably good results with success rates from 60 to 92%.⁶⁻⁹ The failure rate of endopyelotomy increases with more severe hydronephrosis and it is contraindicated in the presence of a crossing vessel. Recently Dimarco et al questioned the durability of

endopyelotomy.¹⁰ With long-term follow-up, they found a progressive decline in success rates over time. Desai et al reported a hybrid technique of percutaneous antegrade endopyeloplasty in 2002.¹¹ They described the use of an endoscopic suturing device (EndoStitch™, AutoSuture USSC, Norwalk, CN) to close a vertical endopyelotomy in a horizontal fashion. While promising, this has been used in small numbers of patients with short-term follow-up to date.

Schuessler et al and Kavoussi and Peters simultaneously reported the first LP in 1993.^{12,13} Over the next decade, a volume of experience was gained which demonstrated success rates equivalent to open pyeloplasty with few complications.¹⁴ The technique essentially duplicates open surgery affording all reconstructive options to the surgeon intraoperatively. Furthermore, stones may be successfully managed without difficulty via laparoscopic pyelolithotomy at the time of pyeloplasty. While not the focus of this chapter, LP has been successfully employed in pediatric cases although the advantages in younger children are controversial.¹⁵ Despite excellent outcomes with LP, a steep learning curve and long operative times have prevented more widespread acceptance.

In the past 5 years, robot assisted surgery has experienced intense growth and enthusiasm by surgeons and patients alike. Procedures that involve intracorporeal laparoscopic suturing, in particular, appear to benefit the most from robotic assistance. In the laboratory setting, robot assistance allows for faster suturing and practice drills as compared with standard laparoscopy.^{16,17} Likewise, surgeons without prior training in laparoscopy acquire skills more rapidly with robot assistance and have less fatigue.¹⁸ While still experimental, robot assistance has also allowed for telementoring of novice surgeons across the Atlantic Ocean.¹⁹

The initial report of robot assistance for LP was using the AESOP™ system (Computer Motion, Goleta, CA) to facilitate laparoscopic camera holding and movement.²⁰ Subsequently, the Zeus™ system (Computer Motion, Goleta, CA) was introduced as the first master-slave system for operative surgical assistance. Although limited by only four degrees-of-freedom, the system offered comparable results with standard LP in the porcine model.

The introduction of the da Vinci™ surgical system (Intuitive Surgical, Mountain View, CA) in 2000 offered significant advantages over standard laparoscopy. The surgeon is seated at an ergonomic console to reduce fatigue and visualization is via three-dimensional binocular lenses with independent light sources, which offer shadowing, and depth perception

Table 17.1 Reported case series of robot assisted laparoscopic pyeloplasty in adults

Reference	Institution	Patients (n)	Operation time (min)	Suture time (min)	Hospital stay (days)	Technique	Approach	Conversion rate	Complications	Success rate	Mean follow-up (months)	Comments conclusions
Yohannes, 2003 ³¹	Creighton	1	300	45	4	A-H	transperitoneal Running 3–0 Stent 1 week	0	0	No reported		First case, feasible, safe
Gettman, 2002 ²³	Innsbruck Mayo	6 Robot assisted vs. 6 pure laparoscopy	140/78 235/100	70/13 120/28	4 4	A-H (4)/ Fenger (2) A-H (4)/ Fenger (2)	transperitoneal Running 4–0 Vicryl Stent 3–6 weeks	0	0	100%	3	Robot faster, especially with A-H
Gettman, 2002 ²²	Innsbruck	9	139	62	4.7	A-H	transperitoneal Running 4–0 Vicryl Stent 6 weeks	0	1 open repair renal pelvis leak	89%	4.1	
Peschel, 2004 ²⁴	Innsbruck Mayo	49	124	NR	NR	A-H (40) Y-V (7) Fenger (2)	transperitoneal Running 4–0 Vicryl Stent 6 weeks	0	1 open repair renal pelvis leak	97% (40 of 41 with follow-up)	7.4	10 patients with secondary UPJ
Hubert, 2003 ²⁵	CHU DeNancy	12	153 (console time)	47	NR	A-H	transperitoneal Running 6–0 Stent 6 weeks	0	0	62.5% (5 of 8 with normal follow-up IVP)	NR	2 clearly improved, 1 slightly improved on IVP
Munver, 2003 ²⁶	Cornell	10	168	42	3	A-H	transperitoneal	0	0	90% (9/10 I stricture, endopyelotomy)	3	
Palese Munver Stifelman Dinlec DelPizzo J Endourol 2005 ³²	Cornell NYU Beth Israel	35	216	63	2.9	A-H	transperitoneal Running or interrupted 4–0 Stent 4–6 weeks	0	1 UTI, 2 pyelo, 1 gluteal compartment	94% (33/35 I 15% fxn failure, went on to nephrectomy I stricture, endopyelotomy)	7.9	Multi-institutional
Palese, Dinlec Stifelman DelPizzo JSL 2005 ³³	Cornell NYU Beth Israel	38	225	64	2.9	A-H	transperitoneal Running or interrupted 4–0 Stent 4–6 weeks	0	1 UTI, 2 pyelo, 1 gluteal compartment	94% 36/38 I 15% fxn failure, went on to nephrectomy I stricture, endopyelotomy	12.2	Multi-institutional I horseshoe kidney, 2 stones

(Continued)

Table 17.1 (Continued)

Reference	Institution	Patients (n)	Operation time (min)	Suture time (min)	Hospital stay (days)	Technique	Approach	Conversion rate	Complications	Success rate	Mean follow-up (months)	Comments conclusions
Bentaz, 2003 ²⁴	JW Goethe University Frankfurt	11	197	NR	5.5	A-H	transperitoneal Int 3-0 Vicryl Stent 5-6 weeks	0	1 patient with pain after stent removal, replaced, patient now asymptomatic, stent-free	100%	12	No prior laparoscopy experience, operative times improved with experience
Mendez-Torres, 2005 ²⁸	Tulane	32	300	NR	1.1	A-H (31) Fenger (1)	transperitoneal Running 4-0 Vicryl Retrograde Stent 6 weeks	0	1 UTI, 1 migrated stent repositioned	16 of 18 with follow-up > 6 months 1 pain unobstructed 1 obstructed	8.6	5 patients stone removed, renal bic operative times improved with experience, suggest retrograde subxiphoid stent, assistant port
Atug, 2006 ²⁴	Tulane	37 primary vs 7 secondary	219 279	NR	1.1 1.2	A-H (44)	transperitoneal Running 4-0 Vicryl Stent 6 weeks	0	0	100%	13.5 10.7	RALP feasible for secondary UPJ, but longer operative times
Bernie, 2005 ³⁵	Indiana	7 Robot assisted vs 7 Pure Laparoscopy	324 312	NR	2.5 3	A-H (4), ND (3) A-H (6), ND (1) A-H (23) Y-V (3)	transperitoneal Running 4-0 PGA stent 6 weeks	0	1 febrile UTI, 1 hematuria 2 leaks, resolved	100%	10 24	No difference with prior laparoscopy experience
Siddiq, 2005 ³⁰	Miami	26	245	47	2	A-H (23) Y-V (3)	transperitoneal preoperative stent	0	1 febrile UTI, 1 leak, 1 hernia	Subjective 95% Objective 100%	6 (median)	4 patients with secondary UPJ
Patel, 2005 ²⁹	Urology Centers of Alabama	50	122	20	1.1	A-H	transperitoneal Running 3-0 Monocryl Stent 3 weeks	0	1 patient with pain after stent removal, replaced, now asymptomatic, stent-free	100%	11.7	Largest series operative times improved with experience

A-H, Anderson-Hynes; ND, nondismembered; NR, not reported; UPJ, ureteropelvic junction; IVP, intravenous pyelogram; UTI, urinary tract infection; Y-V, Y-V flap.

critical in intracorporeal suturing. Additional advantages include tremor filtering, motion scaling, and instruments with seven degrees-of-freedom which all allow for more precise and efficient surgeon movements.²¹ Current disadvantages of the system include a high cost and lack of haptic feedback that initially impairs surgeon ability to perceive tension applied to tissue and suture.

Gettman et al reported the first series of six cases of robot assisted LP in 2002.^{22,23} In these initial cases, operative times decreased to a mean of 140 minutes compared with 235 minutes for standard LP at their institution. With subsequent reports, decreased operative time appears to remain the dominant advantage of robot assisted pyeloplasty (summarized in Table 17.1).²²⁻³⁵ Outcomes including success rates and complications have otherwise been comparable with those of standard LP.

For these reasons, our preferred initial treatment is either standard or robot assisted LP which duplicates open reconstruction based on the principles of preservation of ureteral blood supply, atraumatic tissue handling, and the creation of a spatulated, watertight, tension-free anastomosis. Access to robot assisted surgical systems may be problematic for some surgeons due to a number of reasons including cost, training, location, and utilization. We currently advocate training and familiarity with both standard laparoscopic and robot assisted approaches to allow the surgeon maximal flexibility and the ability to complete the procedure laparoscopically in the event of a robot malfunction.

OPERATING ROOM SET-UP

Standard laparoscopic pyeloplasty

The surgeon and assistant stand facing the patient's abdomen, and the laparoscopic tower and video monitor are positioned on the opposite side of the table adjacent to the patient's shoulder (Figure 17.3).

Robot assisted pyeloplasty

The patient-side cart approaches the patient's back from the shoulder towards the umbilicus at a 45° angle (Figure 17.4). Once docked, the robotic arms will reach across the flank and angle back towards the upper quadrant. The bedside assistant and scrub stand facing the patient's abdomen. The assistant's monitor may be positioned adjacent to the patient-side cart.

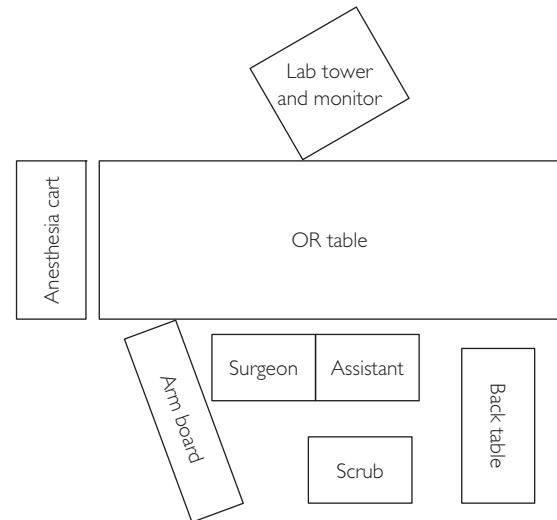


Figure 17.3 Diagram of template for operating room (OR) set-up for left-sided laparoscopic pyeloplasty.

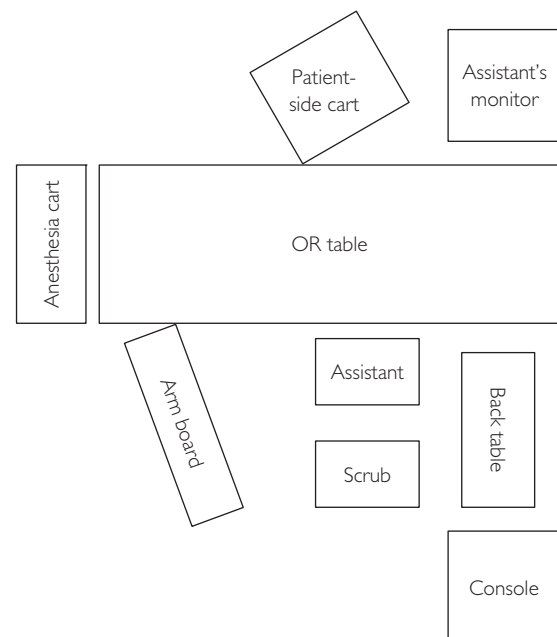


Figure 17.4 Diagram of template for operating room (OR) set-up and robot positioning for left-sided robotic assisted laparoscopic pyeloplasty.

PATIENT PREPARATION

Regardless of the approach to LP, all patients are given a clear liquid diet for 24 hours prior to surgery and provided antibiotic and thromboembolic prophylaxis as per protocol. We routinely utilize cefazolin 2g intravenously and heparin 5000 units subcutaneously.

After adequate general anesthesia, the genitalia are prepped and a flexible cystoscopy is performed in the supine position. A 0.035" angle-tipped hydrophilic guidewire is advanced into the renal pelvis under fluoroscopic guidance. A 5Fr open-ended ureteral catheter is then used to perform a retrograde pyelogram. In the female, a long (28 cm) double-J stent is then placed. In the male, the guidewire is replaced and the penis is kept sterilely prepped into the operative field for later stent placement after the posterior suture line is completed. A Foley catheter is placed to decompress the bladder. The patient is then repositioned in the modified flank position with the affected side elevated (Figure 17.2). With the exception of retroperitoneal cases, we find this position to be universally optimal and feel that it leads to fewer neuromuscular complications than the flank position.

TECHNIQUE

Transperitoneal approach

The Veress needle is used to insufflate the abdomen with carbon dioxide gas. We utilize a three- or four-port technique (Figure 17.5). The fourth port is often useful for the assistant to aid in retraction and suction. Initially, the colon is mobilized medially using cold dissection to expose the anterior kidney and UPJ. We prefer dissection primarily using cold scissors or blunt dissection to minimize the risk of thermal bowel injury and preserve ureteral blood supply. Once identified, we assess the UPJ under vision, evaluate for any missed crossing vessels, and estimate the length of diseased ureter. A stay suture may be placed through the abdominal wall and anterior renal pelvis to aid in retraction and exposure. This is accomplished by passing a 4-0 Vicryl suture on a Keith needle through the abdominal wall, the anterior wall of the renal pelvis, and back out through the abdominal wall. The suture is then secured with a hemostat that may be used to adjust tension (Figure 17.6).

The need for any secondary maneuvers including renal mobilization, flap repair, or ureterocalicostomy is determined. We routinely perform Anderson-Hynes repair in most cases (Figure 17.7). The UPJ is dismembered via a diamond-shaped pyelotomy using laparoscopic Metzenbaum or Potts scissors. Avoid cutting the ureteral stent. We prefer to keep a flap of renal pelvis on the ureteral side, which may be used as a 'handle' to manipulate the ureter during the initial suture placement.³⁶ Concomitant stone extraction may be performed at this time using a flexible cystoscope and basket. Any redundant renal pelvis may be resected at

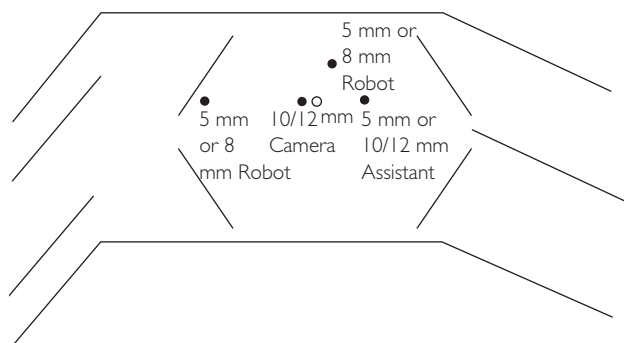


Figure 17.5 Diagram of template for trocar placement for left-sided standard or robotic assisted laparoscopic pyeloplasty.

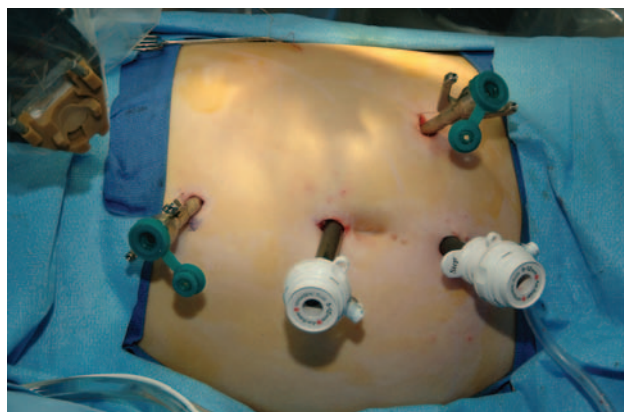


Figure 17.6 Intraoperative photograph demonstrating trocar placement for left-sided robotic assisted laparoscopic pyeloplasty. Note hemostat on stay suture through lateral abdominal wall.

this time as well, taking particular care not to exclude an upper pole infundibulum or calyx. If a crossing vessel is present, the ureter is transposed in relation to the vessel at this time. Next, the ureter is spatulated laterally until healthy ureter is revealed at which point the ureter lays in a relaxed position with an appearance similar to an 'open book'.

The lateral apex of the ureterotomy is then sutured to the dependent apex of the pyelotomy using two interrupted 4-0 Vicryl sutures on RB-1 needles. A short tail of suture is left which may be used to rotate the UPJ or align the tissue for suturing. We feel that it is important to interrupt at least these initial corner sutures to avoid gathering tissue in this narrowest portion of the anastomosis. With these sutures, care must be taken to avoid catching the backwall of the ureter.

Subsequently, the backwall of the anastomosis is routinely closed using a running 4-0 Vicryl suture. The UPJ tissue specimen or 'handle' on the ureter is then sharply excised. The double-J stent is advanced into

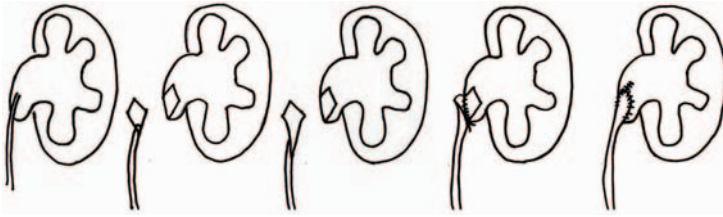


Figure 17.7 Diagram of technique for dismembered Anderson-Hynes repair.

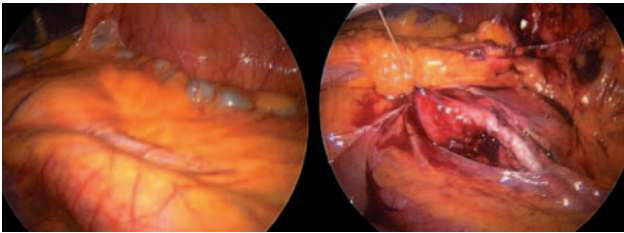


Figure 17.8 Intraoperative photograph demonstrating transmesenteric technique. Note thin mesentery with laterally displaced descending colon. The dilated left renal pelvis can be easily seen as a bulge on the left photograph. In the photograph on the right, a stay suture is used to elevate the renal pelvis to aid in dissection and reconstruction.

the renal pelvis and the anterior wall of the anastomosis is completed with an additional running 4-0 Vicryl. Any remaining pyelotomy is then closed with a final running 4-0 Vicryl, and a 19 Fr Blake drain is brought out through a stab in the abdomen and placed adjacent to the anastomosis. The colon is gently placed back anterior to the kidney and UPJ over the drain. Alternatively, a Y-V plasty or flap repair may be used (Figure 17.4).

Transperitoneal transmesenteric approach

This approach is helpful in thin patients or those with little to no mesenteric fat.³⁷ This is often the case in pediatric cases, or in thin females. The approach is also particularly useful when the ascending or descending colon is located relatively far lateral or even posterior to the kidney (Figure 17.8). In this setting, it can be rather challenging to mobilize the colon anterior to the kidney, often resulting in several small rents in the mesentery. In a well selected patient, the dilated renal pelvis can often be seen through the mesentery. Cold scissors are used to incise the peritoneal surface of the mesentery longitudinally, taking care to avoid any mesenteric vessels. The UPJ is then dissected out in the standard fashion. Placement of a stay suture through the abdominal wall is almost always necessary to help elevate and expose the UPJ. The remainder of the procedure proceeds as described above.

Retroperitoneal approach

While not preferred, rarely this approach may be useful to avoid intraperitoneal adhesions in cases with multiple previous abdominal surgeries; however, it may be particularly difficult for surgeons with limited experience. A lack of familiar landmarks and limited working space for suturing can be challenging, and particular attention must be paid to a thorough search for crossing vessels, which may be more difficult to identify. The patient is typically positioned in the full flank position on a beanbag with port placement shifted laterally. Otherwise, the principles of dissection and reconstruction are identical to those described above.

Robot assisted approach

Although more costly, we currently prefer this approach to pyeloplasty primarily because of decreased operative time and ease of suturing. The patient is prepared and positioned as described above. After insufflation, a 10–12 mm trocar is placed at or near the umbilicus and the two 8 mm robotic trocars are placed (Figure 17.6). A fourth 10–12 mm port is necessary for the assistant to provide suction and pass suture. The initial dissection and identification of the UPJ is done using a standard laparoscopic technique as above. We find this to be most efficient as the large sweeping movements necessary to mobilize the colon tend to be more difficult with the robot. When appropriate, we have successfully performed the transmesenteric procedure robotically. Once the UPJ is exposed, the robot is docked (Figure 17.9). The articulating wristed instruments allow for precise transection of the UPJ and spatulation of the ureter using the Potts scissors. Using two robotic needle drivers, the anastomosis is then completed in a similar manner to that described above.

POSTOPERATIVE CARE

A KUB is obtained in the recovery room to confirm stent position. Postoperatively pain is managed with scheduled ketorolac intravenously and narcotics as



Figure 17.9 Intraoperative photograph demonstrating operating room set-up and robot positioning for left-sided robotic assisted laparoscopic pyeloplasty. Note docked patient-side cart illustrating angle of approach from ipsilateral shoulder towards umbilicus.

needed. The patient is ambulated and given a clear liquid diet on postoperative day 1 and advanced to a regular diet and oral analgesia on postoperative day 2. The Foley catheter is removed early in the morning on postoperative day 2, and drain output is monitored for the next 8 hours. If there is drain output greater than 30ml over 8 hours, then the fluid is sent for creatinine measurement and the Foley is replaced if there is evidence of persistent urine leak. Once there is no evidence of urine leak, the drain is removed. Patients are typically discharged from the hospital on the afternoon of postoperative day 2. The double-J stent is left indwelling for 6 weeks and then removed with flexible cystoscopy in the office. A nuclear renogram is obtained 3 months postoperatively and repeated if any symptoms recur.

RESULTS

The initial reports of LP by Schuessler and Kavoussi and colleagues both described excellent results with success rates of 100%, minimal blood loss, and no complications.^{12,13} The operative times were initially long ranging from 3 to 7 hours, but improved with experience. In the largest series reported to date, Jarrett et al reported a 96% success rate with the first 100 cases at Johns Hopkins.¹⁴ Mean hospital stay was 3.3 days and morbidity was decreased compared with contemporary open pyeloplasty series; however, the mean operative time was still 4.2 hours.

Others have reported success with variations in technique or unique patient populations. Razdan et al

reported a three-trocar technique in 2005 using 5 mm trocars to avoid the need for fascial closure and potentially improve patient discomfort and cosmesis.³⁸ LP also allows for simultaneous treatment of calculus disease without fragmentation. Inagaki et al reported that 20 of 21 patients undergoing simultaneous LP and pyelolithotomy were stone free and all had a patent UPJ.³⁹

LP has been successfully employed in cases of failed previous surgery. In a subset of 25 patients undergoing a secondary pyeloplasty at Johns Hopkins the success rate was 84%.³⁹ The Indiana group similarly reported a success rate of 83% in 36 patients who had previously failed treatment of UPJO.⁴⁰ Success rates of 75% have been reported in patients with the 'worst-case salvage' scenario, after failed open and endoscopic treatment.⁴¹

Robotic pyeloplasty duplicates the technique for LP and as expected the results are comparable. Outcomes and variations in technique are summarized in Table 17.1.^{22–35} The most significant advantage is operative time, as the robot allows for more rapid suturing of the anastomosis. Perhaps underestimated, however, is the advantage of more precise deliberate movements afforded by robot assisted surgery. Increased efficiency and precision are clearly important factors in reconstructive surgery, and are the areas where robot assisted surgery has shown the greatest promise.

CONCLUSION

LP provides a minimally invasive treatment for UPJO that duplicates the principles of open reconstructive surgery with excellent results. While the learning curve and operative time have limited adoption universally, increasing availability and development of robotic technology may result in the rare indication to perform open surgery.

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18 Ureteroscopic endopyelotomy for the treatment of ureteropelvic junction obstruction

Brent Yanke and Demetrius Bagley

INTRODUCTION

Ureteroscopic endopyelotomy can be utilized for the treatment of primary or secondary ureteropelvic junction obstruction (UPJO). It can be employed in selected patients as a single procedure with minimal morbidity and reasonable success. The exact role for each of the techniques available for the treatment of UPJO has been defined and endoscopic endopyelotomy remains a valuable facet in the treatment algorithm based on its simplicity and safety.

SELECTION OF PATIENTS

The majority of patients present with symptoms of pain or discomfort. Symptoms may vary from severe back or flank pain related to acute high grade obstruction to intermittent recurrent pain after ingestion of a large fluid volume. A smaller group of patients have no symptoms but are found to have hydronephrosis on an imaging study such as ultrasound or computed tomography (CT) scan performed for other unrelated purposes.

Evaluation of patients with suspected UPJO should include studies to define the anatomy and the function of each kidney. At present, the most commonly performed initial study is the CT urogram. This study can define the level of obstruction, indicate the degree of hydronephrosis, and delineate the renal parenchyma.^{1,2} The hydronephrotic pelvis can be differentiated from parapelvic cysts by the observation of contrast within the collecting system. As mentioned previously, a renal ultrasound can also define the extent of hydronephrosis. However, the amount and distribution of renal parenchyma remaining does not provide the functional information available from a CT urogram. Ultrasound's overwhelming advantage is the lack of radiation employed for imaging. Renal ultrasonography has been particularly useful in following patients before or after treatment.

Today, excretory urography and intravenous pyelography are less frequently employed due to the widespread availability of CT imaging. These modalities can indicate the extent of hydronephrosis and the amount of functioning parenchyma. They may even define the anatomy of the UPJ and/or the ureter better than the other modalities. However, much of the same information can be gathered by reconstructing the collecting system from the axial slices of the CT scan after intravenous contrast is injected.³ Also, the excretory urogram offers much less information regarding parapelvic cysts or renal masses.

A CT angiogram is particularly useful in defining the vascular supply of the kidney particularly with reference to vessels crossing at the UPJ. Diagnosis of any crossing vessels is particularly important in considering endopyelotomy versus other corrective procedures.¹

One of the most useful studies in the initial evaluation and follow-up of UPJO is the isotopic renal scan.⁴⁻⁶ This study can define the function in each kidney and indicate the drainage on each side. It appears to be indicative of the extent of the obstruction and is particularly useful to follow the patient after treatment. Thus, we routinely perform the scan pre-treatment and early post-treatment to compare the function of the kidneys and the adequacy of drainage. It may indicate recurrent obstruction even when the patient is symptom free.

However, not all patients being evaluated for UPJO require surgical management. A suitable option for select patients, particularly those who are asymptomatic, is to avoid any active interventional treatment and to follow them. This can be considered principally in patients who are symptom free and have good function and preservation of renal parenchyma. Because of the very real risk of deteriorating renal function in the face of persistent obstruction, it is essential to stress to the patient the need to follow actively.

Another option to consider is a patient with an indwelling stent with the intent to maintain chronic stent drainage and change the stent at defined intervals. This approach should be considered in very select

patients who are not candidates for other procedures or who refuse other treatment.

BALLOON DILATATION AND BALLOON CAUTERY ENDOPYELOTOMY

The next more invasive procedure is simple dilatation of the UPJ. This was proposed as 'the Endoburst' procedure in the early 1990s and employed a 30 Fr dilating balloon to rupture the UPJ.⁷ While initial success was reported, longer postoperative follow-up, particularly in patients with congenital UPJO, revealed disappointing results. In treating 40 patients with UPJO, Osther et al reported a 57% success rate in those with congenital UPJO when symptoms debuted after the age of 18 years and only a 25% success rate when symptoms appeared before the age of 18 years.⁸ Overall, it has had limited success but still may have some role in patients with a well defined short narrow UPJO, especially those rare patients with ureters too small for placement of a ureteroscope. Long-term success may be achieved in some patients.

In an effort to create a durable, yet simplified, endopyelotomy treatment, an electrocautery cutting wire was added to the dilating balloon. Chandhoke et al described a retrograde endopyelotomy device (Acucise) that consisted of an 8 mm balloon catheter with a 100 μ m electrocautery wire for retrograde incision of the UPJ.⁹ This approach relied on fluoroscopic control and precluded the need for antegrade or retrograde endoscopy during the endopyelotomy. In its current form, Acucise endopyelotomy allows for performance of a retrograde pyelogram, positioning of the apparatus, and incising of the UPJ all with the same device.¹⁰ A stent is placed over the same wire at the end of the procedure. In general, the incision is made from a lateral or posterolateral approach.

Early studies reported higher success rates but with relatively shorter lengths of follow-up. In their initial series, Chandhoke et al demonstrated complete resolution in 67% of the 21 patients who initially had symptoms of upper urinary tract obstruction with partial resolution in another 19%.⁹ In addition, they stated that postoperative studies revealed normal upper tracts in 71% and improvement in another 14% of patients. However, mean follow-up time was 3.8 months and preoperative evaluation was not standardized. Later studies with longer follow-ups of 24 months or more have reported success rates of 32–75% with the majority under 60%.^{11–14} It has been noted that success is related to the presence of perioperative extravasation of contrast

during fluoroscopy.¹¹ In addition, the presence of crossing vessels has been reported to minimize success. Lechevallier et al treated 36 patients with UPJO by Acucise as the first-line treatment.¹² On multivariate analysis, they found that the presence of a crossing vessel decreased the success rate, with only 45% of those with a crossing vessel having both subjective and objective improvement compared with 81% of those without a crossing vessel.

Performing an Acucise endopyelotomy in the presence of a crossing vessel can also lead to potentially life threatening hemorrhage.^{15–17} Schwartz et al reported five complications in 52 patients treated over a 5-year period.¹⁶ Of these, three involved injury to an accessory lower pole renal artery while another was due to laceration of an ovarian vein. The lower pole renal artery injuries were successfully treated by embolization while the ovarian vein injury led to eventual abdominal exploration, ovarian vein ligation, and nephrectomy. Significantly protracted postoperative hematuria should raise the index of suspicion of vascular injury. It should be stated that use of this procedure without appropriate preoperative imaging confirming the absence of crossing vessels puts the patient at potential risk.

ENDOPYELOTOMY

Endopyelotomy assumed a major role in the treatment of UPJO, although recently it has been superseded by the success achieved with laparoscopic pyeloplasty. Endopyelotomy can be performed by one of several techniques. The initial reports were of percutaneous antegrade endopyelotomy employed by a cold knife incision.^{18,19} It offers the advantage of being able to treat considerable renal calculus burdens during the same procedure. This technique, however, requires the establishment of a nephrostomy tract before the endopyelotomy can be done as well as longer hospital stays. Ureteroscopic endopyelotomy soon followed, initially described as pyelolysis using the rigid ureteroscope.²⁰ It was difficult to reach the UPJ with a rigid ureteroscope and the availability of flexible instruments prompted the wider acceptance of flexible ureteroscopic endopyelotomy.^{21–24}

Laparoscopic, robotic assisted or open surgical pyeloplasty yields a higher success than endopyelotomy in the treatment of UPJO. However, pyeloplasty remains a more invasive technique no matter the approach. The rapid acceptance of laparoscopy among urologists is rapidly making laparoscopic pyeloplasty the most common treatment of patients with obstruction especially

in light of the limited morbidity and high success rate of the procedure.

BENEFITS OF URETEROSCOPIC ENDOPYELOTOMY

Ureteroscopic endopyelotomy has many benefits which may make it the first choice for treatment of UPJO in selected patients. It can be carried out as a single procedure without the need for placement of a percutaneous nephrostomy tract or pre-stenting when performed with a small diameter flexible ureteroscope. The patient is maintained in the lithotomy position during the procedure. It is not necessary to place him in the prone position as for an antegrade endopyelotomy where nephrostomy access is needed. A ureteral stent is placed to offer internal drainage. The patient experiences essentially no discomfort except for that related to the stent. There is a short (less than 24 hour) or no hospital stay for the procedure.

TECHNIQUE OF URETEROSCOPIC ENDOPYELOTOMY

Cystoscopy is performed to gain access to the ureter and inspect the bladder. A retrograde ureteropyelogram is performed usually with a cone tipped catheter. This technique enables assessment of the ureter to define any narrowed or strictured areas as well as the UPJ. The retrograde ureteropyelogram depicts an image of the UPJ which cannot be achieved by any other imaging modality. It can demonstrate the length of a narrowing, the exact course of the ureter in that section, and in some cases define the presence of a high insertion. Retrograde ureteropyelography is an essential step in ureteroscopic endopyelotomy.

The next step in our technique is to perform endoluminal ultrasound of the UPJ in order to define the anatomy most accurately²⁵⁻²⁷ (Figure 18.1). We can identify the presence or absence of crossing vessels and, when visualized, assess both their size and location (Figure 18.2). This is more accurate than CT angiography.^{28,29} We can also define the location and length of any septum which indicates a high ureteral insertion into the UPJ. The 6Fr ultrasound probe is passed over a wire and advanced to the level of the UPJ. The anatomy is then carefully defined at that location. The ultrasound probe gives a cross-sectional image. It is essential to have a guidewire in place in order to determine the orientation of the ultrasound catheter relative to the guidewire. The guidewire must be

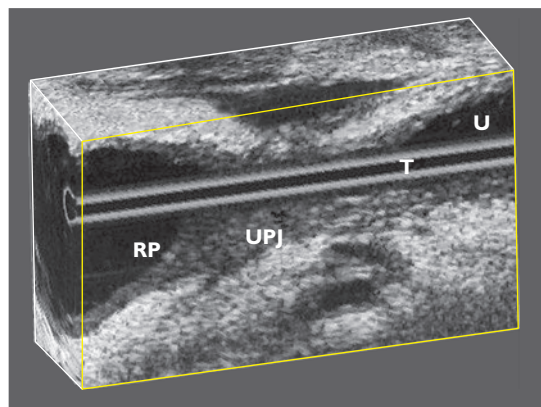


Figure 18.1 Endoluminal ultrasound of normal ureteropelvic junction (UPJ). Three-dimensional reconstruction. RP, renal pelvis; T, transducer probe; U, ureter.

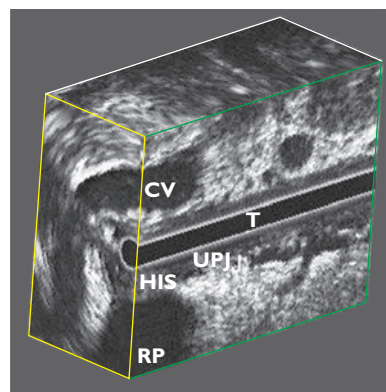


Figure 18.2 Endoluminal ultrasound of ureteropelvic junction (UPJ) obstruction. Three-dimensional reconstruction showing crossing renal vessel (CV) and high insertion of ureter. T, transducer probe; RP, renal pelvis; HIS, high inserting septum.

directly lateral or medial to the ultrasound probe to give this orientation. If it is located anteriorly or posteriorly, then it will appear superimposed on the ultrasound transducer fluoroscopically making it impossible to orient the sonographic image. If there is a crossing vessel, this location is defined by the orientation of the ultrasound catheter and the position of the tip of the catheter fluoroscopically. When there is a septum indicating a high insertion, the length is determined by fluoroscopic indication of the ultrasound transducer at the proximal and distal limits of the septum.

The information gained from endoluminal sonography and retrograde ureteropyelogram determines the site for incision. In particular, incising the UPJ at the location of a crossing vessel is strictly avoided. When endoluminal ultrasound is not available, the CT angiogram is employed to indicate the presence of crossing

vessels. Endoscopic visualization of pulsations from a crossing vessel is not sufficiently specific to allow localization of the vessel. The entire area may likely be pulsating because of transmission from the nearby great vessels and renal vessels.

The flexible ureteroscope is then passed into the ureter up to the level of the UPI. The safety guidewire must remain in place to give access for placing the stent or catheter after the endopyelotomy is performed. It may be impossible to pass a ureteroscope under direct vision once the incision has been made. There is usually some bleeding and there can be significant distortion of the anatomy once the renal pelvis drains and with fluid seeping into the retroperitoneal space. The tip of the ureteroscope is oriented to the site of incision. Location and length of the high insertion can be confirmed by simultaneous fluoroscopy and endoscopic visualization. The ureteroscope is passed to the most proximal portion of the ureter and its position confirmed fluoroscopically. The lower margins of the renal pelvis also are identified fluoroscopically by contrast retained within the collecting system. The ureteroscope is then withdrawn within the ureter to a point parallel to the lower margin of the renal pelvis. The length from that point to the proximal margin of the ureter is the length of the septum.

The incision can be made with an electrode or a holmium laser. A small diameter electrode such as a 2 Fr straight tip electrode or a 3 Fr extendable needle point device can be used. Alternatively, the angled Rite-Cut electrode extends the reach slightly beyond the ureteroscope. The electrosurgical unit is placed on pure cut and a setting of 30 W is used. A non-conductive irrigant such as water can be used during the actual incision. Most recently, the holmium laser has been employed (Figure 18.3). A small fiber of 200 μm is preferable to allow more deflection of the ureteroscope. This enables better application of the laser to the mucosa. It is activated at a higher energy and frequency such as 1.2–1.5 J per pulse and 10–15 Hz, respectively.

In order to make the incision with either device, the ureteroscope is extended into the renal pelvis and

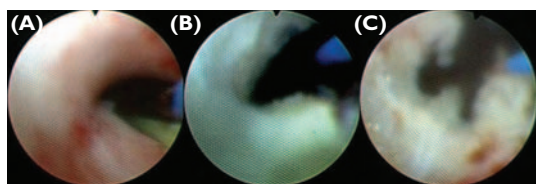


Figure 18.3 Ureteroscopic holmium laser endopyelotomy. (A) Ureteropelvic junction obstruction with safety wire and holmium laser in view; (B) initial incision through septum; (C) incision through entire ureteropelvic wall into surrounding fat.

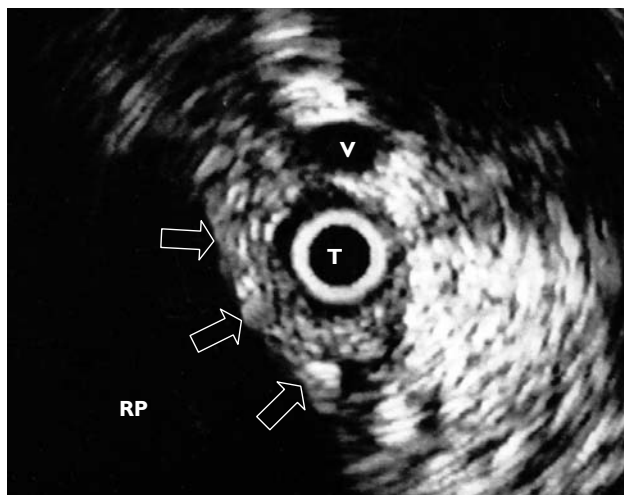


Figure 18.4 Two-dimensional endoluminal ultrasound of ureteropelvic junction obstruction before incision. RP, renal pelvis; V, crossing vessel; T, transducer probe; arrows, high inserting septum.

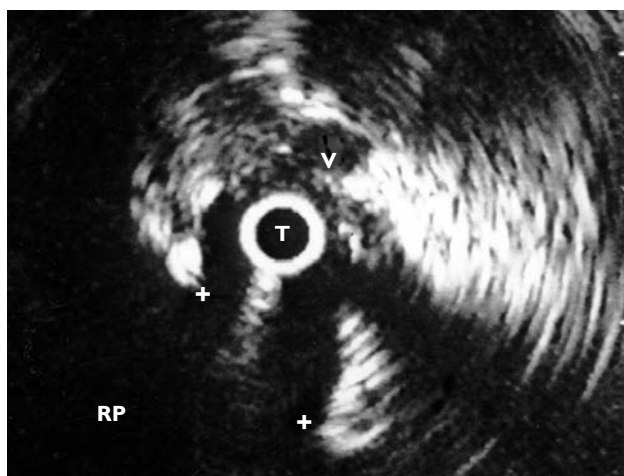


Figure 18.5 Two-dimensional endoluminal ultrasound of ureteropelvic obstruction after incision. T, transducer probe; V, crossing vessel; RP, renal pelvis; crosses, incised high inserting septum.

deflected toward the site of the incision. Following this, the cutting device is positioned within view. The ureteroscope is withdrawn and the cutting device is activated as the tissue is encountered. The ureteroscope is passed through the area of incision with the device activated. The area is then reinspected and any remaining bands of tissue can be divided under vision. After the incision, the ureteroscope is removed. Endoluminal ultrasound can be utilized to confirm adequacy of incision (Figures 18.4 and 18.5). We have generally placed a balloon catheter at this point to calibrate the incision and open the adventitia. The balloon is filled with contrast only to the pressure required to open the balloon. Adequacy of incision is

confirmed by fluoroscopic imaging of the balloon. If any narrow bands remain, the ureteroscope is replaced and that area incised. In this way, the UPJ is not dilated but simply calibrated to determine the adequacy of the initial incision. The incision should be made through the entire thickness of the ureter. The wall of the ureter can be seen endoscopically and the periureteral adventitia and fat can be visualized.

A double pigtail stent is then placed over the wire with the proximal curl located well within the renal pelvis. A stent approximately 2 cm longer than would be required for simple drainage should be employed to be certain that the proximal coil does not withdraw into the area of incision. A Foley catheter is left in the bladder for 24 hours after incision to provide low pressure drainage until the endopyelotomy is sealed. The stent should be left in place for several weeks with recommendations varying from 6 to 10 weeks.

POSTOPERATIVE CARE

In most cases, the patient is discharged from the hospital within 24 hours. The stent can be removed at a predetermined period without further visualization. Urinalysis and urine culture can be helpful to define the presence of any urinary infection which should be treated before the stent is removed. Cystoscopy and stent removal can usually be performed in the office except for younger patients who may require anesthesia.

FOLLOW-UP IMAGING

Initial post-treatment imaging is performed at 6 weeks after stent removal with a renal ultrasound. Although some hydronephrosis is normal at this point, persistent and increasing hydronephrosis is more prominent than that seen preoperatively. This suggests reobstruction and should prompt further studies. Six weeks to 3 months after removal of the stent, an isotopic renal scan is performed to define the function and drainage. This study also is performed during follow-up at intervals determined by the findings. If there is excellent drainage, then it is performed at increasing intervals, while any question of drainage will prompt more frequent studies.

RESULTS OF URETEROSCOPIC ENDOPYELOTOMY

Most early endopyelotomy studies reported success rates of over 85%, however, many were percutaneous

series with relatively short follow-up.^{19,24,30,31} In order to avoid the significant discomfort from the percutaneous tract, Clayman et al evaluated the efficacy of a retrograde approach.²⁴ In 1990, they published their early series of ten patients undergoing ureteronephroscopic endopyelotomy. They utilized a cutting electrode that was passed through either a flexible or a rigid ureteroscope. During the average follow-up of 12 months, flank pain had largely dissipated in all patients. Even though subsequent imaging was not standardized as patients underwent a Whitaker test, an excretory urogram, or a renal scan, decreased or no obstruction was demonstrated in nine of the ten patients. These results were reproduced by Tawfik et al who evaluated 37 patients for endopyelotomy.³² Five patients were excluded from the procedure based on endoluminal ultrasound findings. The remaining 32 patients were followed for a mean of 10 months. Success, strictly defined as being pain free and having resolution of obstruction on diuretic renal scan, was attained in 87.5% of the patients.

With its widespread availability and increasing popularity, the holmium:YAG laser began to replace the cutting electrode as the endopyelotomy instrument of choice. Biyani et al reported their initial experience with laser endopyelotomy in eight patients.³³ They performed a posterolateral incision and followed with a renogram 3 months after the procedure. The average operative time was 37.5 minutes and with a mean follow-up 12.4 months, the overall success rate of 87.5% was equivalent to endopyelotomy series employing either a cold knife or a cutting electrode. In a follow-up study, these authors reported only two failures among 20 patients (10%) followed for a mean of 34 months after the procedure.³⁴ An additional three patients had unsatisfactory outcomes that the authors attributed to poor preoperative renal function. In a more recent study comparing antegrade and retrograde endopyelotomy, Minervini et al performed a subset analysis comparing diathermy and laser energy success rates within the retrograde group.³⁵ The energy source used to treat the first 18 patients was diathermy while UPJ incision in the next 30 patients was completed using the holmium:YAG laser. The success rate of laser endopyelotomy was 80% compared with 53% for diathermy. Because the sample size was relatively small, the difference approached but did not reach statistical significance ($p = 0.0626$). Of note, the authors found that retrograde endopyelotomy had a significantly lower complication rate and hospital stay than the antegrade approach. In addition, the overall success rate, while not statistically significant, was higher in the retrograde group (70%) than in the

antegrade group (56%) with mean follow-up of 24 and 46 months, respectively. Finally, a more recent study by Ponsky and Stroom confirmed the durability of ureteroscopic laser endopyelotomy.³⁶ They reported a long-term success rate of 74.2% with a mean follow-up of 75.6 months. The authors strictly defined success as resolution of symptoms and radiographic relief of obstruction.

When assessing management options for UPJO, it is important to consider whether it is a primary or a secondary treatment. Several authors have reported improved outcomes for initial versus salvage endopyelotomy.^{37,38} Ost et al compared primary and secondary treatment success rates for laparoscopic pyeloplasty and antegrade endopyelotomy in 100 patients.³⁸ While 35 of 38 (92%) primary percutaneous endopyelotomies were deemed successful, only seven of 12 (58%) secondary procedures were likewise successful. Laparoscopic pyeloplasty proved to be equally successful for primary (100% in 29 patients) and secondary (95.2% in 21 patients) repair. When considering a secondary endopyelotomy, the type of initial repair has been shown to impact success rates. Ng et al found a 71.4% success rate when a combination of endopyelotomy approaches followed a failed open pyeloplasty but only a 37.5% success rate when endopyelotomy followed a failed endourologic procedure.³⁷ In comparison, salvage open pyeloplasty had a success rate of 100% and 94.1% when following an initial failed pyeloplasty and initial failed endopyelotomy, respectively. While salvage endopyelotomy following a failed endourologic treatment has been shown to be less than satisfactory, its use after failed pyeloplasty has been confirmed by others with reported success rates as high as 87.5%.³⁹

It is likely that repeat endopyelotomy has a high failure rate following initial endopyelotomy due to the presence of crossing vessels. This would also explain the low failure rate of salvage dismembered pyeloplasty whether performed open or laparoscopically. As mentioned previously, endoluminal ultrasound remains the most effective method to detect crossing vessels and should be utilized before each potential endopyelotomy. The importance of crossing vessels found during endopyelotomy was shown in an early study by Conlin and Bagley.⁴⁰ With a minimum of 1-year follow-up, ureteroscopic endopyelotomy was successful in 17 of 21 patients (81%). Twelve of these patients were found to have crossing vessels and the success rate in this group was only 67% compared with 100% among the 11 patients without crossing vessels. In a study comparing retrograde endopyelotomy with laparoscopic pyeloplasty, Parkin et al confirmed the negative

impact of crossing vessels on endopyelotomy results.⁴¹ With a mean follow-up of 19 months among endopyelotomy patients, they noted success in 11 of 13 (85%) without crossing vessels compared with six of 11 (55%) with crossing vessels. There was only one failure in the 18 patient pyeloplasty group which had a mean follow-up of 15.1 months. These authors recommended laparoscopic pyeloplasty as the treatment of choice when crossing vessels are present.

Finally, in their series of 133 consecutive ureteroscopic endopyelotomies, Mendez-Torres et al described two additional factors that predisposed to treatment failure.⁴² First, they identified poor outcomes in patients with long-standing obstruction and concomitant decrease in renal function. This was particularly evident in ipsilateral renal units with split renal function of less than 20%. They also found that the presence of an overly distended renal pelvis in which drainage did not improve with indwelling stent often led to insignificant improvement in symptoms and drainage after endopyelotomy. The authors recommended alternative treatment, either pyeloplasty or nephrectomy, for patients with patulous redundant renal pelvis and borderline salvageable renal function.

CONCLUSION

Ureteroscopic endopyelotomy provides a minimally invasive option for the treatment of UPJO with proven efficacy. While laparoscopic pyeloplasty has become the most commonly performed procedure, endopyelotomy remains an appropriate option in properly selected patients with success rates of over 80%. With the widespread use of ureteroscopy and the holmium laser, retrograde endopyelotomy can be performed by most urologists making it a valuable tool in the treatment of UPJO.

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19 Percutaneous management of ureteropelvic junction obstruction

Robert J Stein and Mihir M Desai

INTRODUCTION

Ureteropelvic junction obstruction (UPJO) is the most common congenital condition affecting the kidney with an incidence of approximately one in 400 live births. Indications for surgical treatment may include presence of pain, pyelonephritis, secondary renal stones, and decreased renal function. Preoperative studies should include a diuretic renal scan for determination of differential renal function and severity of obstruction as well as an anatomic study such as an excretory urogram or retrograde pyelogram in order to evaluate for coexisting ureteral pathology and optimally define the UPJ anatomy. Computed tomography (CT) can be additionally helpful for identifying renal calculi as well as lower pole crossing vessels.

Various surgical options for treatment of UPJO include open and laparoscopic pyeloplasty, antegrade (percutaneous) endopyelotomy, percutaneous endopyeloplasty, retrograde (ureteroscopic) endopyelotomy, and Acucise® (Applied Medical, Rancho Santa Margarita, CA) endopyelotomy. The choice of surgical intervention in an individual patient is based primarily on variables such as ipsilateral renal function, degree of hydronephrosis, length of stricture, presence of crossing vessels, presence and size of renal calculi, and history of prior surgery on the UPJ. Patient and surgeon preference also play an important role in selecting the type of surgical intervention.

In this chapter we present technical aspects and results of percutaneous endopyelotomy and endopyeloplasty.

PERCUTANEOUS ENDOPYELOTOMY

Endopyelotomy is based on the principle of intubated ureterotomy initially reported by Albarran in 1903¹ and later popularized by Davis in 1943.² Percutaneous endoscopic incision of the UPJ (pyelolysis) was first described by Wickham and Kellet³ and subsequently popularized by Badlani et al. as endopyelotomy.⁴

Technique of endopyelotomy

Percutaneous endopyelotomy is performed under general anesthesia with appropriate antibiotic coverage.⁵ Initially, a retrograde pyelogram is performed to confirm the length of obstruction and document absence of distal ureteral pathology. An open-ended catheter is then positioned within the renal collecting system under fluoroscopic visualization. The patient is then positioned prone and the collecting system is opacified with contrast material infused through the open-ended catheter. Using fluoroscopic guidance, percutaneous renal access is obtained through an appropriate upper or interpolar calyx. The percutaneous tract is dilated to 30 Fr using either sequential dilators or a balloon dilatation system and a nephroscopic sheath is positioned within the collecting system.

Various techniques have been described to perform the percutaneous endopyelotomy incision. The essential aim is to create a full-thickness incision across the obstructing segment extending into normal pelvis proximally and normal ureter distally. Several authors have recommended using 'cold-knife' for performing endopyelotomy. Different energies such as cutting current and holmium:YAG laser have also been employed for creating the incision. There are no data to support the advantage of one technique over the others and the ultimate choice of technique (energy versus cold incision) is typically based on surgeon preference. Additionally, the UPJ can be dilated with either a balloon or rigid dilator in order to better define the strictured segment and provide an adequate space for making the incision. The endopyelotomy incision is typically created laterally based on the anatomic studies of Sampaio and Favorito⁶ in order to avoid inadvertent injury to a crossing vessel. In these studies using casts of the collecting system and renal vascular anatomy, they identified posterior lower pole crossing vessels in 6.2% of subjects studied. After complete incision of the UPJ, secondary dilatation with a balloon or rigid dilator may be performed to break any fibrous bands that may remain.

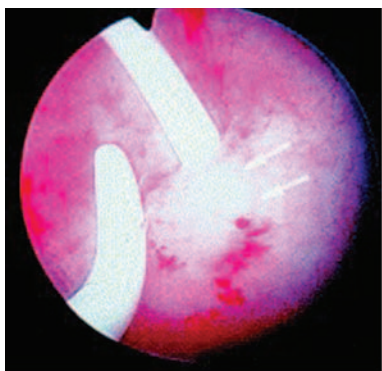


Figure 19.1 Pyeloscopic view after placement of the endopyelotomy stent. The area to be incised is defined by the relationship of the UPJ and the position of the stent (arrows).

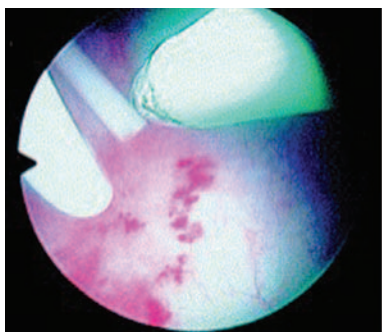


Figure 19.2 An acorn-tipped Bugbee electrode is used to incise the UPJ over the stent.

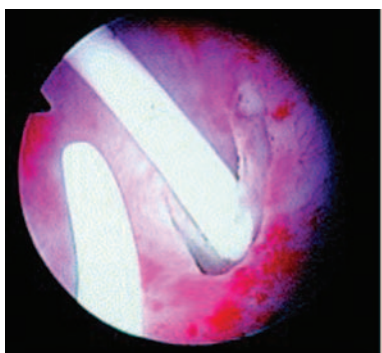


Figure 19.3 The apex of the incision is now at the dependent portion of the renal pelvis and is widely patent.

At the Cleveland Clinic we have employed a technique of placing a stent first and then incising over the stent using a Bugbee electrode⁷ (Figures 19.1–19.3). The advantage of this approach is that it obviates the need to place the relatively larger endopyelotomy

stent after making the incision and thereby reduces the risk of avulsion at the UPJ. Also, the stent accurately defines the site of incision and cutting over the stent optimally marsupializes the ureter into the pelvis. A tapered endopyelotomy stent is then positioned fluoroscopically over the guidewire with placement of the wider segment at the level of the incised UPJ. Usually, the largest stent that the ureter and UPJ will accommodate is passed under nephroscopic and fluoroscopic visualization. Finally, a nephrostomy tube is positioned within the collecting system and secured to the skin. A nephrostogram should demonstrate proper positioning of this tube and extravasation of contrast at the site of full thickness endopyelotomy. The nephrostomy tube is removed 2 days later and the double-J stent is removed after 6 weeks. Recently, tubeless percutaneous endopyelotomy has been reported without any additional morbidity.

Other variations to the technique for incising the UPJ include the transpelvic approach and invagination technique that ultimately achieves the same end result as described above.

Results

Success rates for antegrade endopyelotomy have ranged from 56% to 100% with most studies ranging between 70 and 90%.^{8–18} Several groups have compared antegrade endopyelotomy with other treatments for UPJO^{12–21} (Table 19.1). The majority of these studies document decreased morbidity of endopyelotomy compared with pyeloplasty, albeit with decreased efficacy. Several authors have suggested better results for antegrade endopyelotomy if treatment is reserved for select patients without crossing vessels, severe hydronephrosis, or poor ipsilateral renal function (vide infra). Antegrade endopyelotomy is contraindicated when stricture length is longer than 2 cm or when the patient has uncorrectable coagulopathy.

Several small series of pediatric patients undergoing antegrade endopyelotomy have also been reported. The most common indication for percutaneous endopyelotomy in children is a secondary UPJO after failed open pyeloplasty. Kavoussi et al²² reported success in all four of their patients undergoing endopyelotomy after failed pyeloplasty although two patients did require an additional endoscopic procedure. Figenshau et al²³ reported a 62% success rate in eight children undergoing antegrade endopyelotomy for primary UPJO and 100% success in nine patients with secondary UPJO after pyeloplasty. Tan et al²⁴ reported success in only 58% of 17 children undergoing percutaneous endopyelotomy, but all three attempts in children

Table 19.1 Comparative studies. Adapted from reference 21

Investigators	Techniques compared	Study type	Success rates	Comments
Brooks et al ¹²	Laparoscopic pyeloplasty (n = 12) vs. open pyeloplasty (n = 11) vs. antegrade endopyelotomy (n = 13) vs. Acucise (n = 9)	Retro	Laparoscopic and open pyeloplasty 100% Antegrade endopyelotomy 77% Acucise 78%	Authors recommend laparoscopic pyeloplasty or Acucise for management of UPJO without renal calculi In the setting of renal calculi, percutaneous endopyelotomy should be considered
Schenkman and Tarry ¹³	Open pyeloplasty (n = 20) vs. antegrade endopyelotomy (n = 8) in pediatric population	Retro	Pyeloplasty 93% Endopyelotomy 88%	Nearly equivalent success rates between the two procedures Slightly longer hospital stay with pyeloplasty (0.8 days) Endopyelotomy >\$2800 more expensive and longer operative time
Shalhav et al ¹⁴	Antegrade endopyelotomy (n = 83) vs. Acucise (n = 66)	Retro	Antegrade endopyelotomy 89% Acucise 71%	Trend of success for antegrade procedure higher than Acucise for 1° UPJO but not statistically significant Antegrade technique has longer operative time, longer hospital stay, higher costs, and more complications
Banerjee et al ¹⁵	Open pyeloplasty (n = 23) vs. antegrade endopyelotomy (n = 23)	Retro	Pyeloplasty 93% Endopyelotomy 100%	Equivalent or better success rate with endopyelotomy Shorter hospital stay (4.9 days vs. 10.7 days) and shorter operative time for endopyelotomy
Karlin et al ¹⁶	Open pyeloplasty (n = 32) vs. antegrade endopyelotomy (n = 56)	Retro	Pyeloplasty 95–98% Endopyelotomy 87.5%	Equivalent complication rates between the techniques Operative time, analgesic requirement, hospital stay, and time to resumption of normal activity all less with endopyelotomy
Lam et al ¹⁷	Antegrade endopyelotomy (n = 64) vs. retrograde endopyelotomy (n = 29)	Retro	Antegrade 81.3% Retrograde 75.9%	Endopyelotomy success lower than pyeloplasty Most antegrade/retrograde procedures with Acucise No significant difference between the two approaches Better success with antegrade approach in setting of severe hydronephrosis
Minervini et al ¹⁸	Endopyelotomy: retrograde laser (n = 30), diathermy (n = 18) vs. antegrade (n = 19)	Retro	Laser 80% Retrograde diathermy 53% Antegrade diathermy 56%	Trend toward highest success rates with retrograde laser approach Higher complication rate with antegrade vs. retrograde approach (42% vs. 12%) Authors suggest retrograde laser for endopyelotomy
Ost et al ¹⁹	Laparoscopic pyeloplasty (n = 50) vs. antegrade endopyelotomy (n = 50)	Retro	Pyeloplasty 100% Endopyelotomy 92%	Three endopyelotomy failures all occurred in patients with severe hydronephrosis Recommend laparoscopic pyeloplasty when severe hydronephrosis or renal function <30%
Desai et al ²⁰	Endopyeloplasty (n = 15) vs. antegrade endopyelotomy (n = 15) vs. laparoscopic pyeloplasty (n = 14)	Retro	Endopyeloplasty 100% Endopyelotomy 87.6% Pyeloplasty 93%	Trend of better success rate of endopyeloplasty compared with endopyelotomy Stent duration of endopyeloplasty 2 weeks vs. 6 weeks for endopyelotomy Operative time pyeloplasty > endopyeloplasty > endopyelotomy

Retro, retropective.

with secondary UPJO were successful. Faerber et al²⁵ reported 80% success with antegrade endopyelotomy in five children with secondary UPJO.

Complications of antegrade endopyelotomy range from 0 to 42%.^{9,10,18,26,27,29} The most concerning acute complication is hemorrhage requiring transfusion, usually occurring in 0–10% of patients. Bleeding may occur from either the percutaneous tract or the endopyelotomy incision site. If conservative treatment fails, angioembolization is the initial intervention of choice. If angioembolization is unsuccessful, nephrectomy may rarely be necessary. Other rare but major complications have included ureteral avulsion, ureteral stricture, Page kidney, and ureteral intussusception.^{26,27,29} Stent migration and urinary tract infection are other complications that have been reported.

Crossing vessels

In a series of 102 patients undergoing antegrade endopyelotomy, Van Cangh et al⁸ obtained preoperative angiography on 80% of patients. With a 5-year mean follow-up they reported a success rate of 86% with no crossing vessel present versus only a 42% success rate with a crossing vessel. Pardalidis et al²⁸ used Doppler ultrasound and CT in order to assess for crossing vessels or severe hydronephrosis in 22 patients. In the 14 patients with mild to moderate hydronephrosis and no crossing vessel, they reported a 92.8% success rate with percutaneous endopyelotomy. Knudsen et al¹⁰ reported that 15/18 (83%) of their patients failing antegrade endopyelotomy had crossing vessels noted at open pyeloplasty. In contrast, Gupta et al²⁹ reported crossing vessels in only 24.1% of 54 patients undergoing open exploration after failed antegrade endopyelotomy. In conclusion, most reports examining the effect of crossing vessels suggest that they increase the incidence of failure after endopyelotomy, yet this issue remains unresolved.

Hydronephrosis

Grading of hydronephrosis is somewhat subjective but most studies have used the Society of Fetal Urology grades 3 or 4 to classify severe hydronephrosis. Gupta et al²⁹ reported a success rate of only 50% with grade 4 hydronephrosis versus a 96% success rate with grade 2 hydronephrosis. Sim et al¹¹ noted a decrease in the success rate of antegrade endopyelotomy treatments from 84% to 64% in the setting of severe hydronephrosis. In a retrospective series, Lam et al¹⁷ found that antegrade endopyelotomy using the Acucise device was more effective for the treatment of UPJO with severe

hydronephrosis than retrograde Acucise endopyelotomy (success rate of 66.7% and 20%, respectively). Overall, in the setting of severe hydronephrosis, given the poor results with endopyelotomy, pyeloplasty with pelvic reduction should be considered first line therapy.

Poor renal function

Gupta et al²⁹ examined the effect of differential renal function on success of endopyelotomy in 401 patients undergoing antegrade endopyelotomy. They reported a 54% success rate in the setting of poor renal function (differential function <25%), 80% success with moderate renal function (25–40% differential function), and 92% success with good renal function (differential function >40%). Kapoor et al^{27b} performed antegrade endopyelotomy on 34 patients with decreased renal function. A successful result was noted in 90% of 21 patients with a glomerular filtration rate (GFR) of 15–25 ml/min, while only a 62% success rate was noted in 13 patients with a GFR of 5–15 ml/min. Overall, antegrade endopyelotomy in the setting of poor renal function has been associated with worse outcomes.

Stenting after endopyelotomy

Work by Davis et al³⁰ demonstrated complete healing of the urothelium at 3 weeks and 90% healing of the muscularis at 6 weeks after ureterotomy. Based on these results, stenting for 6 weeks after percutaneous endopyelotomy has historically been recommended. Soria et al³¹ used a porcine model of UPJO to investigate optimal stent dwell time following antegrade endopyelotomy. Two subjects developed a urinoma after removing the stent just 1 week following the procedure. On pathologic analysis, there was a significant increase in UPJ luminal diameter for the 6-week dwell time group compared with the 1-week group. There was no significant difference in luminal diameter between the 3-week dwell time group and the 6-week group. Mandhani et al³² investigated duration of stenting in 26 patients undergoing antegrade endopyelotomy with subsequent placement of a 14/7 Fr graded endopyelotomy stent. At mean follow-up of 21–22 months the radiographic success rate was 92.3% for the group undergoing 2 weeks of stenting versus a 90.3% success rate for 4 weeks of stenting.

Danuser et al³³ compared placement of a 14 Fr versus a 27 Fr stent at the UPJ after antegrade endopyelotomy. They found that early success rates at 7–8-week follow-up were better for the larger stent (94% versus 83%), while the difference at longer-term, 2-year, follow-up was even more pronounced for the larger stent

(93% versus 71%). Hwang et al³⁴ noted an 84% success rate with a 6 Fr double-J stent compared to a 93.3% success rate with a 14/7 Fr endopyelotomy stent in 25 patients undergoing antegrade endopyelotomy. The difference was not significant but suggests a trend toward improved results with a larger stent size. Despite preliminary data favoring 3–6-week dwell time and larger stent size after antegrade endopyelotomy, more investigations with longer follow-up are needed to determine the optimum stent size and stent duration.

Long-term failure

Durability of successful results from endopyelotomy has recently been questioned. Late failures can result in loss of renal function long after the patient is considered 'cured'. The length of time required for follow-up usually with history and diuretic nuclear scintigraphy is debated. Dimarco et al³⁵ compared the long-term success of antegrade endopyelotomy and pyeloplasty. For antegrade endopyelotomy at 3-, 5-, and 10-year follow-up, success rates for primary UPJO were 63%, 55%, and 41%, respectively. Interestingly, pyeloplasty (laparoscopic and open) failures also occurred after many years with success rates being 85%, 80%, and 75%, respectively. Albani et al³⁶ reported that in their experience of 127 antegrade and retrograde endopyelotomies followed up to 128 months, there were no failures that occurred after 3 years and that most failures occurred within 12 months. Knudsen et al reported in their series of antegrade endopyelotomy that the mean time to failure was 15 months.¹⁰ For now, long-term follow-up of patients undergoing endopyelotomy does seem prudent. The optimal duration and frequency of follow-up as well as timing of radiographic studies is as yet undetermined.

Percutaneous endopyelotomy in congenitally abnormal and transplant kidneys

Jabbour et al³⁷ described percutaneous endopyelotomy in nine patients with congenitally abnormal kidneys (pelvic kidney $n = 4$, horseshoe kidney $n = 5$) with a 78% success rate. Percutaneous access for the pelvic kidneys was established using a retrograde approach under laparoscopic guidance. Aron et al³⁸ also reported successful antegrade, laser endopyelotomy for a pelvic kidney that already had percutaneous access from failed pyeloplasty and pyelolithotomy. Two other groups have also reported successful antegrade endopyelotomy in patients with horseshoe kidneys using a cold knife and posterolateral incision.^{39,40}

Schumacher et al⁴¹ described three renal transplant patients with elevation in serum creatinine and normal renal biopsies. UPJO was diagnosed and all patients underwent percutaneous endopyelotomy successfully using a cold knife and 14/8.2 Fr endopyelotomy stent.

Management of secondary UPJO

In general, endopyelotomy should be considered for failed pyeloplasty and a pyeloplasty for failed endopyelotomy. Jabbour et al⁴² performed antegrade endopyelotomy on 72 patients who had failed open pyeloplasty and reported a success rate of 87.5%. Varkarakis et al⁴³ reported ten failures from a large series of laparoscopic pyeloplasty. Six of seven secondary endopyelotomy procedures were successful. In contrast, only one of two balloon dilatations and none of one repeat pyeloplasty were successful. Ng et al⁴⁴ in a review of 22 patients treated endoscopically for primary treatment failure, reported a 71.4% success rate for secondary endopyelotomy after failed pyeloplasty and only a 37.5% success rate after failed endopyelotomy. Hoenig et al⁴⁵ reported success in 88% of cases of endopyelotomy after failed open pyeloplasty and only in 71% after failed endopyelotomy.

Endopyeloplasty

Percutaneous endopyeloplasty reproduces the Fenger-plasty technique by horizontal suturing (Heineke-Mikulicz) of a vertical endopyelotomy incision using a nephroscope through a solitary percutaneous tract. For the endoscopic repair, Desai et al used a laparoscopic suturing device (SewRight SR5, LSI Solutions, Victor, NY), which was modified to enable its use through a 26 Fr nephroscope (Karl Storz, Culver City, CA).⁴⁶ In a chronic porcine study, the authors demonstrated evidence of primary, full-thickness, wound healing with significantly less scar formation and wound contraction compared with endopyelotomy. The result was a wider caliber UPJ than in endopyelotomy specimens that had undergone wound healing by secondary intention. All of the porcine subjects successfully underwent endopyeloplasty with a mean suturing time of 29.4 minutes, and all demonstrated resolution of the experimentally created UPJO.

Clinical experience

Initially, nine patients with primary UPJO underwent endopyeloplasty with relief of obstruction subjectively and radiographically in all cases.⁴⁷ Preoperative

imaging was used to identify and exclude patients with crossing vessels or more than 1 cm stenotic segments. Subsequently, Desai et al²⁰ compared endopyeloplasty with antegrade endopyelotomy and laparoscopic pyeloplasty. Using strict symptomatic and radiologic follow-up parameters, successful resolution of UPJO was obtained in 100% of endopyeloplasty patients (11.6-month follow-up), 87.6% of endopyelotomy patients (31.4-month follow-up), and 93% of pyeloplasty patients (20-month follow-up).

The total number of endopyeloplasty treatments by the authors for UPJO is now 55.⁴⁸ Exclusion criteria included patients with secondary UPJO, more than 1 cm segment stenosis, presence of crossing vessels on preoperative imaging, and prior recent surgery on the UPJ. Percutaneous endopyeloplasty was technically successful in 53 patients; suture cut-through in a friable UPJ precluded endopyeloplasty in two patients. Mean operative time was 103 minutes and mean time for suturing was 27 minutes. Intraoperative complications included irrigation fluid extravasation ($n = 1$), and suture cut-through ($n = 2$). Postoperative complications included pyrexia requiring prolonged JJ ureteral stenting ($n = 5$). Endopyeloplasty was successful in relieving obstruction in 51 patients. One patient with a crossing vessel failed at 12 months and the other patient failed immediately after stent extraction.

Ost et al¹⁹ reported only a 40% success rate with endopyeloplasty in five patients with UPJO. The authors postulated that failures may have been due to difficulty suturing after UPJ dilatation with resultant mucosal thinning and bothersome mild bleeding. One caveat is that care should be taken to maintain as much hemostasis as possible to optimize visibility for suturing. More recently, Sharp et al⁴⁹ demonstrated the feasibility of completely dismembered endopyeloplasty by circumferential incision of the UPJ and subsequent reanastomosis in an acute porcine UPJO model.

Percutaneous endopyeloplasty has shown promising early results for treatment of primary UPJO. Further studies at other institutions are necessary to validate these findings.

CONCLUSION

Percutaneous endopyelotomy is less morbid and aesthetically superior but has a decreased rate of success compared with open pyeloplasty. Antegrade endopyelotomy may be more advantageous than retrograde endopyelotomy in patients with coexistent stone disease and where retrograde access is difficult. Endopyeloplasty

may provide a comparable success rate to open pyeloplasty with an equivalent incision to antegrade endopyelotomy in select patients but further studies are required to validate these results. With the increasing use of a laparoscopic or robotic assisted approach for pyeloplasty, the minimally invasive advantages of endoscopic techniques are comparatively diminishing, and the role of percutaneous approaches to treat UPJO is being reassessed. An enduring indication in which to consider percutaneous endopyelotomy is in cases of secondary UPJO after failed pyeloplasty.

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20 Laparoscopic surgery in horseshoe and pelvic kidneys

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INTRODUCTION

Horseshoe kidney malformation is the most common congenital renal anomaly and has an incidence of 0.25% (1:400 live births).¹ As with other fusion anomalies, it is more common in males, with a 2:1 ratio. The etiology likely involves abnormal migration of the metanephric blastema toward the midline with consequent communication and fusion of the lower poles. The tissue that connects both poles, the isthmus, is bulky and usually parenchymal. The isthmus prevents cranial migration of the mid-portion of the renal mass superior to the inferior mesenteric artery, and the kidney does not complete its normal rotation. The pelvis is positioned anteriorly and the ureters cross ventral to the isthmus.

These kidneys have variable and often complex renal arterial anatomy. One or many renal arteries may originate from the aorta, inferior mesenteric artery, or even pelvic vessels. The isthmus is generally positioned anterior to the great vessels and usually has its own blood supply. Several other genitourinary anomalies can occur in patients with horseshoe kidney, including hypospadias, bicornuate uterus, septate vagina, ureteral duplication, ectopic ureterocele, cryptorchidism, vesicoureteral reflux, and polycystic renal disease.

The course of the ureters anterior to the bulky isthmus can cause urinary stasis with an associated higher incidence of stone disease and ureteropelvic junction obstruction (UPJO). Urolithiasis is the most common complication of horseshoe kidney with an incidence of 21–60%.² UPJO occurs in 25–33% of horseshoe kidneys.³

Renal ectopia describes the condition of a mature kidney failing to achieve its normal location. The incidence of ectopic kidney at autopsy varies from 1 in 500 to 1 in 1200 with no gender predisposition. The position of an ectopic kidney can be pelvic, lumbar, abdominal, thoracic, or crossed. Most ectopic kidneys demonstrate a component of malrotation, usually resulting in an anterior position of the renal pelvis.

Pelvic ectopia, a kidney located at the level of the sacrum, below the aortic bifurcation, is noted in 1 in 2100–3000 autopsies.¹ The supplying vasculature is

most commonly derived from the distal aorta, aortic bifurcation, and iliac vessels. Similar to the horseshoe malformation, pelvic kidneys can be associated with other genitourinary anomalies including bicornuate or unicornuate uterus with atresia of one horn, rudimentary or absent uterus, hypospadias, vesicoureteral reflux, and duplication of the urethra. In comparison with orthotopic kidneys, pelvic kidneys are more susceptible to development of UPJO (22–37%) and urinary stone formation.⁴

Although most pelvic and horseshoe kidneys are clinically asymptomatic, several concomitant pathologies including nephrolithiasis, UPJO, and renal masses may require surgery. Careful preoperative planning is necessary due to the anomalous site and anatomy of these kidneys. Nevertheless, laparoscopic surgery is by no means contraindicated in these patients and the benefits of the minimally invasive approach are similar to those for patients with orthotopic kidneys.

HORSESHOE KIDNEYS

Pyeloplasty

In the horseshoe kidney, UPJO is often due to one or more of several features including anomalous blood supply with a crossing vessel, high insertion of the ureter, or an obstructing isthmus posterior to the proximal ureter. Open pyeloplasty has been the gold standard treatment for UPJO. Reported overall success rates range between 90 and 100% for patients with orthotopic kidneys and 55 and 80% for patients with horseshoe kidneys.^{5–7} Since its introduction in 1993 by Schuessler et al, laparoscopic pyeloplasty has demonstrated excellent results with improved recovery.^{8–11} Bauer et al noted essentially equivalent rates of postoperative symptomatic improvement in 77 patients after either open or laparoscopic pyeloplasty (91% versus 90% improvement, respectively).⁹ In addition, radiographic resolution was noted in 98% of patients after laparoscopic pyeloplasty. Klingler et al similarly noted equivalent success rates after open or laparoscopic pyeloplasty and reported less postoperative

Table 20.1 Pyeloplasty in horseshoe kidneys

Author	n	Technique	Approach	Operating room time (min)	Blood loss (ml)	Hospital stay (days)
Bove et al, 2004 ¹²	5	Laparoscopic	Transperitoneal	195	122	3.2
Hsu et al, 2003 ¹³	1	Laparoscopic	Retroperitoneal	400	30	7.6
Nadler et al, 2003 ¹⁴	1	Hand assisted laparoscopy	Transperitoneal	230	300	3
Chammas et al, 2006 ¹⁶	3	Robotic	Transperitoneal	148.3	100	7.6

pain, lower analgesic requirement, and shorter hospital stay in the laparoscopic group.¹⁰ Siqueira et al reported 94% subjective and objective success in patients who underwent laparoscopic pyeloplasty.¹¹

Several studies have addressed laparoscopic pyeloplasty in anomalous kidneys^{12–15} (Table 20.1) Bove et al¹² performed laparoscopic pyeloplasty in 11 patients with urinary tract anomalies, including three patients with pelvic kidneys and five with horseshoe kidneys. They reported a mean operative time of 195 minutes and mean estimated blood loss of 122 ml. No patient in this series required transfusion and there were no major complications. Average length of hospital stay was 3.2 days. The success rate was 91% based on clinical and radiographic success during a follow-up of 32.6 and 21.3 months, respectively.

For horseshoe kidneys the transperitoneal approach is more frequently used because it provides better working space for reconstructing the collecting system. However, the retroperitoneal approach is feasible. Hsu and Presti performed an extraperitoneal laparoscopic pyeloplasty in a horseshoe kidney.¹³ The operative time was 400 minutes and hospital stay was 7.6 days.

For open surgical repair of UPJO in horseshoe kidneys, it was thought that the isthmus should be divided, isthmectomy, followed by dismembered pyeloplasty and nephropexy of the ipsilateral kidney. Nadler et al reported a case of a patient with horseshoe kidney and UPJO in which hand-assisted laparoscopic dismembered pyeloplasty and isthmectomy were performed.¹⁴ Electrocautery was used to score the capsule of the isthmus and the separation was completed using the Harmonic Scalpel (Ethicon Endosurgery). Hemostasis was achieved using manual compression, argon-beam coagulation, Surgicel® soaked in thrombin, and fibrin glue. The patient's symptoms resolved, and follow-up imaging revealed successful isthmectomy and improved drainage. Nevertheless, several studies now suggest that isthmectomy is not necessary and, indeed, it is rarely performed in contemporary series.^{12,14,15}

Chammas et al reported a three patient series of robotic assisted laparoscopic pyeloplasty for management of UPJO in horseshoe kidneys.¹⁶ The mean

operative time was 148.3 minutes, mean estimated blood loss was less than 100 ml, and mean hospital stay was 7.6 days. All patients had durable clinical and radiographic success during a mean follow-up of 21 months. One patient required subsequent shockwave lithotripsy to treat a residual stone, while another had an episode of pyelonephritis.

As in anatomically normal kidneys, the type of repair performed is at the surgeon's discretion and is based on the unique anatomy of the UPJ. Dismembered pyeloplasty is the most common technique, and can be used in nearly any situation especially with concomitant crossing vessels. In patients with short intrinsic stenoses, a Heineke-Mickulicz repair can be considered for reconstruction. A Y-V plasty may be an option for patients with a high ureteral insertion.

Technique

Our dismembered pyeloplasty technique begins with cystoscopy and retrograde pyelography in order to ensure that no other ureteral pathology exists and to demonstrate the length of the narrowed segment. A 4.7 Fr × 26 cm double-J stent is then positioned with the proximal curl in the renal pelvis. The smaller caliber stent allows us to spatulate and suture without significant interference during the laparoscopic pyeloplasty.

To accommodate the caudally displaced horseshoe kidney, all trocars are positioned more caudal and medial than in our conventional port placement for transperitoneal renal laparoscopy. Figure 20.1 demonstrates port placement depending on laterality of UPJO. The colon is reflected medially to expose the kidney, and the ureter is usually identified coursing over the isthmus. The pelvis is dismembered obliquely and the ureter spatulated laterally using 'cold' endoshears.

The ureteropelvic anastomosis is performed using continuous 4-0 Vicryl suture on an RB-1 needle. Starting at the apex of the ureteral spatulation, one suture each is used for the anterior (dyed) and posterior wall (undyed) of the anastomosis. After the pyelo-ureteral anastomosis is complete, the two sutures are tied to each other. Any remaining pelvic defect, especially in cases

requiring pelvic reduction is sutured using a running 4-0 Vicryl suture. The anastomosis is covered by a flap of perinephric fat whenever possible. A drain is left in proximity to the repair and the ureteral stent is maintained for approximately 6 weeks.

Heminephrectomy

The most common indications for heminephrectomy in a horseshoe kidney are renal mass and non-functioning moiety. Most reports of laparoscopic heminephrectomy in horseshoe kidneys have been for a non-functioning renal moiety, although experience with laparoscopic heminephrectomy for renal tumors is increasing.

Regarding a non-functioning moiety, this is thought to be most commonly due to unrecognized chronic UPJO. In these cases, the renal parenchyma is atrophic and the blood supply is minimal so imaging to define the vascular supply is not routinely necessary. Riedl et al first described the laparoscopic approach for the treatment of a non-functioning moiety and, after that, several cases have been reported.¹⁷⁻²² A number of techniques have been described for dividing the isthmus including use of an endoscopic stapler, electrocautery, microwave coagulator, or bipolar energy. Ao et al reported a case in which they were able to drain the non-functioning hydronephrotic segment laparoscopically, deliver it from a port site, and perform heminephrectomy extracorporeally.¹⁸

Hammontree and Passman²³ reported a hand assisted laparoscopic technique for removal of an autosomal dominant polycystic horseshoe kidney in preparation for kidney transplantation. The surgery was completed successfully with an operative time of 280 minutes and an estimated blood loss of 350 ml.

Laparoscopic removal of a pyonephrotic moiety is challenging because of inflammation and adhesions in addition to the aberrant vasculature, abnormal renal location, and renal isthmus. Modi et al reported a retroperitoneoscopic heminephrectomy of the non-functioning, pyonephrotic right moiety of a horseshoe kidney.²⁴ The operative time was 140 minutes with a blood loss of 75 ml. The hospital stay was 24 hours. The authors suggested that, in experienced hands, retroperitoneoscopic heminephrectomy is a safe and feasible approach for pyonephrotic moieties.

Lane et al reported a case of a 42-year-old man who presented with a non-functioning left moiety and bilateral UPJO in a horseshoe kidney²⁵ (Figure 20.1). Simultaneous transperitoneal laparoscopic left heminephrectomy and right pyeloplasty were performed.

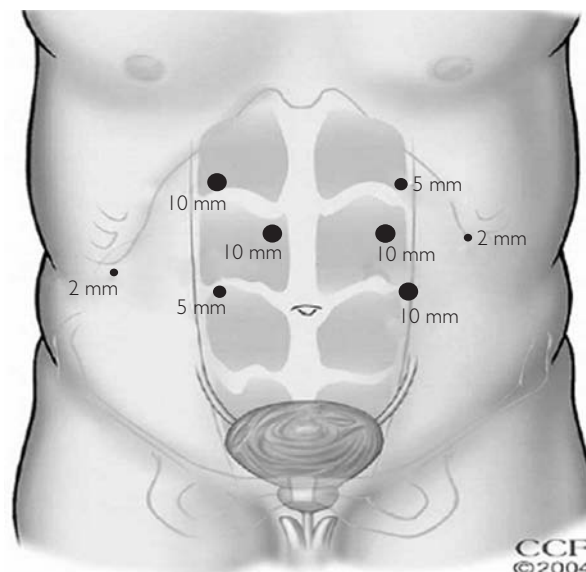


Figure 20.1 Diagram of port placement for right and left laparoscopic intervention in a horseshoe kidney. Ports are placed more medially and caudally than for standard transperitoneal renal laparoscopy, 2 mm ports are placed laterally to aid with retraction. Adapted from reference 23. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

The total operative time was 5.7 hours with a blood loss of 350 ml. There were no complications, and the hospital stay was 3 days.

For laparoscopic heminephrectomy due to renal mass in a horseshoe kidney, vascular variation and the anterior renal pelvis are important considerations. During surgery, accurate knowledge of the number and location of renal vessels is helpful to maintain consistent vascular control and therefore a vascular radiologic study is recommended. Computed tomography (CT) angiography provides excellent detail least invasively. If this modality is not available, conventional arteriography can be performed.

Kitamura et al performed a right retroperitoneoscopic heminephrectomy for tumor.²⁶ The patient had previously undergone open cholecystectomy and appendectomy with panperitonitis. The total operative time was 300 minutes with an estimated blood loss of 60 ml. The patient resumed oral intake on postoperative day 1 and was discharged on day 7. No recurrence was reported during 9 months of follow-up. This was the first reported case of division of the isthmus of a horseshoe kidney using ultrasonic shears for cancer.

Bhayani and Andriole reported left heminephrectomy of a horseshoe kidney for a 6 cm tumor.²⁷ The authors divided the isthmus directly anterior to the aorta with cold shears and oversewed the exposed parenchyma

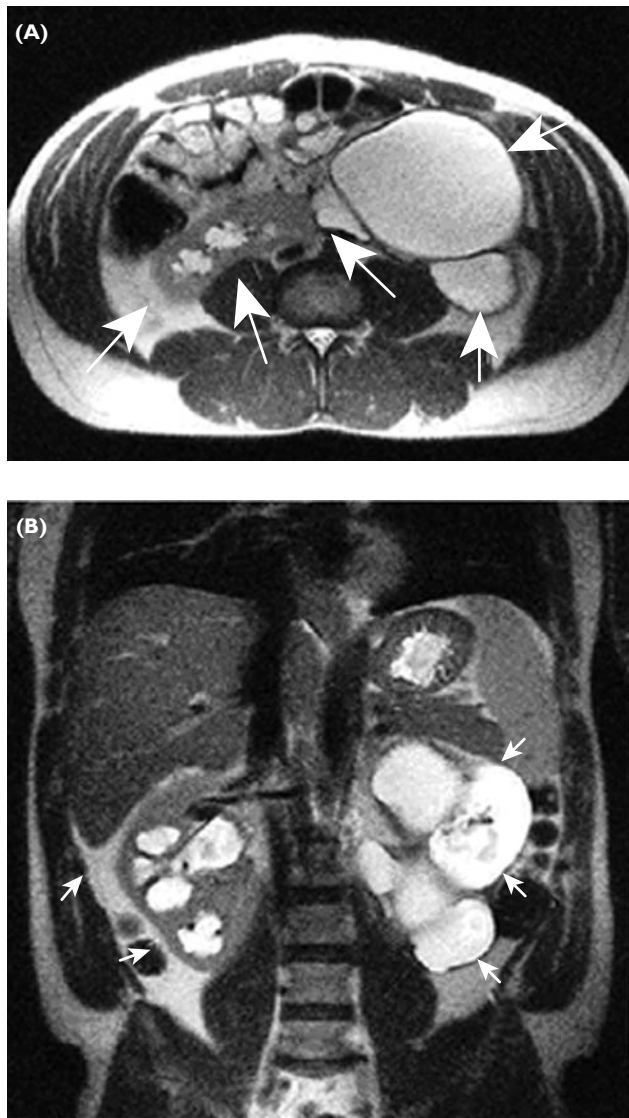


Figure 20.2 Magnetic resonance imaging showing bilateral UPJO on in a horseshoe kidney. (A) Axial image shows right moiety (small arrows) and the hydronephrotic sac of the left renal moiety (large arrows) of the horseshoe kidney. (B) Coronal image shows the hydronephrotic sac of the left renal moiety with minimal remaining renal parenchyma (large arrows). Right renal moiety (small arrows) is seen also with a dilated collecting system. Adapted from reference 23.

after argon beam coagulation. The operative time was 2.75 hours, and the estimated blood loss was 400 ml.

Laparoscopic partial nephrectomy in a horseshoe kidney has been reported. Molina and Gill performed retroperitoneoscopic partial nephrectomy for a posterolateral tumor²⁸ (Figure 20.3). The tumor was completely excised with cold Endoshears, the collecting system was oversewn, and capsular sutures were secured over Surgicel bolsters. Estimated blood loss was 100 ml, total operative time was 3.3 hours, and warm ischemia time was 31 minutes.

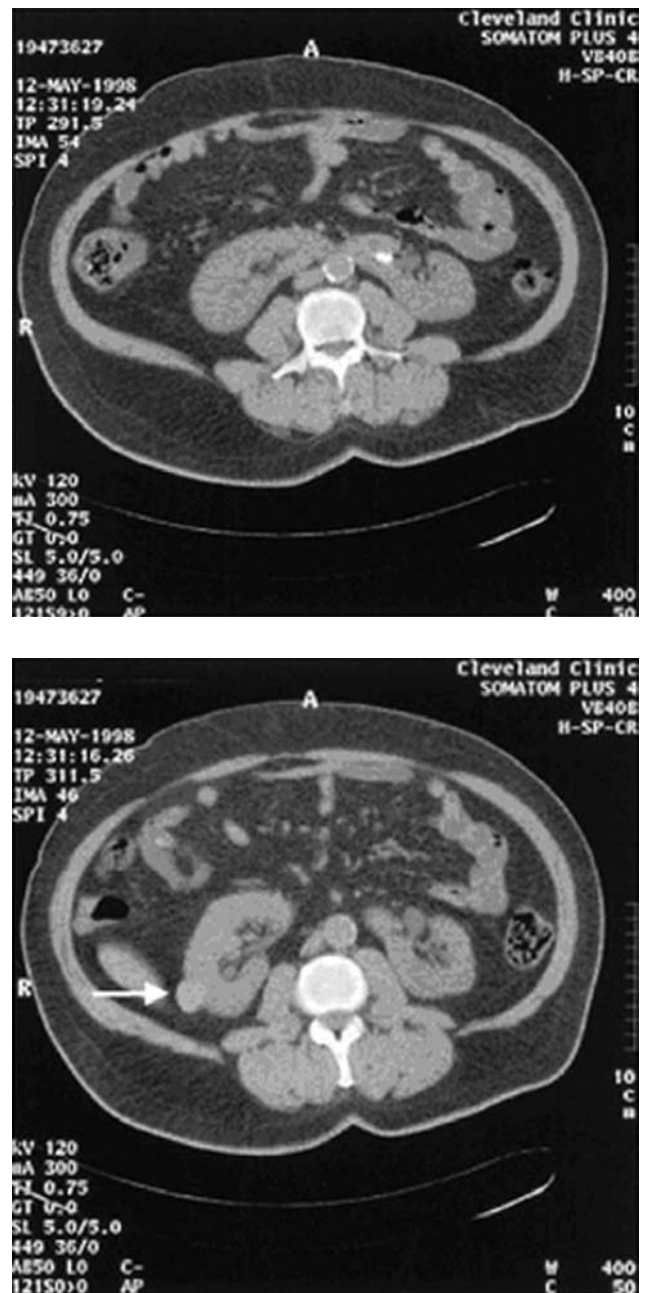


Figure 20.3 Horseshoe kidney with 2-cm exophytic tumor (arrow) in the posterolateral aspect of the right renal moiety. Adapted from reference 24.

Tsivian et al reported transperitoneal laparoscopic partial nephrectomy for a 2 cm tumor in the isthmus of a horseshoe kidney.²⁹ Vascular control was obtained with a vessel loop, the tumor was excised, and hemostasis was obtained with capsular stitches over a Surgicel bolster. Operative time was 3.5 hours, estimated blood loss was 70 ml, and the patient was discharged on postoperative day 3.

Reports of laparoscopic heminephrectomy and partial nephrectomy in horseshoe kidneys are summarized in Table 20.2.

Table 20.2 Heminephrectomy and partial nephrectomy in horseshoe kidneys

Author	n	Indication	Procedure	Approach	I	Reconstruction technique	Complications
Riedl et al, 1995 ¹⁷	1	Non-functioning moiety	Heminephrectomy	Transperitoneal	Endo GIA stapler	NA	None
Ao et al, 1996 ¹⁸	1	Non-functioning moiety	Heminephrectomy	Transperitoneal	Extracorporeal electrocautery	NA	None
Donovan et al, 1997 ¹⁹	1	Non-functioning moiety	Heminephrectomy	Transperitoneal	Endostapler	NA	None
Hayakawa et al, 1999 ²⁰	1	Non-functioning moiety	Heminephrectomy	Transperitoneal	Microwave coagulator	NA	Prolonged ileus
Dasgupta et al, 2005 ²¹	1	Non-functioning moiety	Heminephrectomy	Transperitoneal	Endo GIA stapler	NA	None
Pantankar et al, 2006 ²²	1	Non-functioning moiety	Heminephrectomy	Transperitoneal	Bipolar energy	NA	None
Modi et al 2006 ²⁴	1	Pyonephrosis	Heminephrectomy	Retropertitoneal	Endo GIA stapler	NA	None
Molina and Gill 2003 ²⁸	1	Renal mass	Partial nephrectomy	Retropertitoneal	NA	Intracorporeal suturing	None
Kitamura et al 2003 ²⁶	1	Renal mass	Heminephrectomy	Retropertitoneal	Harmonic Scalpel, argon	NA	None
Bhayani et al 2005 ²⁷	1	Renal mass	Heminephrectomy	Transperitoneal	Cold shear, suturing, argon	NA	None
Tsivian et al 2007 ²⁹	1	Renal mass	Partial nephrectomy	Transperitoneal	NA	Intracorporeal suturing	None

NA, not applicable.

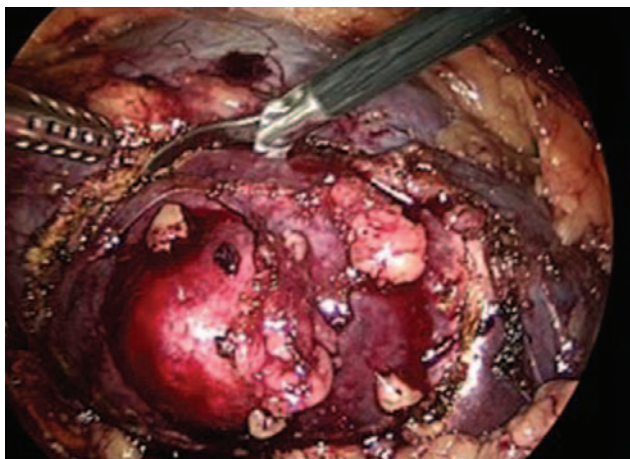


Figure 20.4 Tumor excision with cold Endoshears in a laparoscopic partial nephrectomy.

Technique

A summary of our transperitoneal partial nephrectomy technique is herein described. Three-dimensional CT imaging is obtained in all patients in order to specifically define renal and vascular anatomy. The patient is initially placed in the lithotomy position and an open-ended ureteral catheter is passed over guidewire into the renal pelvis for later injection of dilute indigo carmine dye. A Foley catheter is then placed and the patient is positioned in 60° modified flank position.

Figure 20.1 demonstrates our standard port positions for horseshoe kidney partial nephrectomy depending on the side of the tumor. The overlying bowel is mobilized medially and the ureter is retracted anteriorly taking special care not to strip the ureter of its surrounding tissue. All relevant renal vasculature is then completely exposed. Gerota's fascia is excised from the renal capsule widely in order to expose a large margin around the tumor as well as to provide ample renal mobilization. Intraoperative ultrasound is then used to mark a 1 cm margin around the tumor edge and laparoscopic bulldog clamps are employed to clamp each of the vessels independently. After tumor excision with cold Endoshears (Figure 20.4), retrograde injection of dilute methylene blue is performed to identify any collecting system entry. Areas of collecting system entry as well as larger vessels in the partial nephrectomy bed are oversewn using a running 0 vicryl suture on a CT-1 needle. Two prepared Surgicel bolsters are tightly buttressed into the partial nephrectomy bed with interrupted capsular number 1 Vicryl sutures on a CTX needle. Bulldog clamps are removed sequentially, revascularizing the kidney. The specimen is extracted intact through an extended port site incision after being placed in an Endocatch bag.

PELVIC KIDNEYS

Urolithiasis in pelvic ectopic kidneys presents unique challenges. These kidneys are often malrotated and are surrounded posteriorly and laterally by the bony pelvis. Paterson et al reported only a 54% stone-free rate with shock wave lithotripsy as monotherapy in such kidneys.³⁰ Furthermore, the patient must be positioned prone for the treatment due to the intervening bony pelvis. Similar to shock wave lithotripsy in orthotopic kidneys, stone-free rates decrease with increasing size of stones as well as with lower pole location of calculi. Standard percutaneous nephrolithotomy (PCNL) with the patient in the prone position is usually impossible to perform as the bony pelvis precludes attempts to puncture the kidney posteriorly. Anterior puncture with the patient in the supine position is possible but can be risky due to intervening bowel.

Laparoscopic assisted percutaneous nephrolithotomy

If renal stones are too large for ureteroscopy or shock wave lithotripsy or if flexible ureteroscopy is unavailable, removal of renal stones from pelvic kidneys is preferentially performed percutaneously under ultrasound or laparoscopic guidance. Holman and Toth reported a series of 15 patients treated with laparoscopy assisted PCNL in which all stones were removed successfully with only one complication of delayed urine leak.³¹ Zafar and Lingeman described a modification in which intracorporeal suturing of the renal puncture site and ureteral stent placement allowed the surgeons to forego leaving a transperitoneal nephrostomy tube.³²

Aron et al described a patient with a left pelvic ectopic kidney and a prior history of open pyelolithotomy who presented with multiple recurrent stones in the pelvic kidney.³³ The authors exposed the anterior surface of the kidney by mobilizing the overlying sigmoid colon laparoscopically, and a percutaneous tract was established under combined laparoscopic and fluoroscopic guidance. The same authors also described a transmesenteric technique of laparoscopic assisted PCNL in a thin patient, therefore avoiding mobilization of bowel.³⁴ Dos Santos et al also described successful laparoscopic assisted PCNL for a 1.5 cm stone with an operative time of 90 minutes.³⁵

Important technical caveats for performing laparoscopic assisted PCNL include careful preoperative imaging to define the location of major blood vessels and their relation to the calices, Trendelenburg positioning with a gentle tilt of the table away from the

kidney in order to allow gravity retraction of the bowel, suction of irrigant from the peritoneum at the conclusion of the procedure, and an attempt to complete the procedure in one stage to minimize the risk of intestinal obstruction.

Laparoscopic pyelolithotomy

Laparoscopic pyelolithotomy has been described by several groups. Harmon et al reported successful laparoscopic pyelolithotomy for a 2.5 cm stone burden in a pelvic kidney.³⁶ Due to the poorly accessible position of the pyelotomy, the collecting system was not closed and the patient required bladder catheterization and ureteral stenting for 2 weeks. Chang and Dretler described use of intraoperative fluoroscopy for localization of a 2 cm renal stone during laparoscopic pyelolithotomy.³⁷ The pyelotomy was reapproximated by laparoscopic suturing, although extravasation occurred requiring prolonged Foley catheterization. Hoenig et al reported a laparoscopic pyelolithotomy for a 2.5 cm stone in a pelvic kidney.³⁸ Closure of the renal pelvis was performed with the Endostitch™ device (Autosuture, Norwalk, CT) and total operative time was 310 minutes. The patient resumed a regular diet and was discharged home on the first postoperative day.

Ureteropelvic junction obstruction

Recently, Schwab et al reported a series of four children who underwent laparoscopic pyeloplasty for UPJO in pelvic kidneys.³⁹ Mean operative time was 2.1 hours, mean hospital stay was 2.2 days, and mean time to return to normal activity was 2 weeks. No intraoperative complications were noted. The authors demonstrated that the transperitoneal laparoscopic approach is feasible in children with pelvic kidneys.

Davis and Wolf performed a laparoscopic pyelovesicostomy for UPJO in a pelvic kidney.⁴⁰ The estimated blood loss was 100 ml, and the operative time was 207 minutes. When deciding on this approach, the risk of ascending infection resulting in pyelonephritis must be balanced with the wider anastomosis, which possibly decreases the risk of recurrent stenosis. Further experience with this technique is needed to better define the risks and merits.

Wadhwa and Hemal reported a transmesenteric approach for laparoscopic pyeloplasty in a pelvic kidney.⁴¹ During the procedure, the distended renal pelvis was well defined posterior to the sigmoid mesentery and therefore the authors approached the

UPJ directly. Laparoscopic intracorporeal suturing was used for the dismembered repair and total operative time was 122 minutes.

Laparoscopic pyeloplasty is a reasonable option for treating UPJO in pelvic ectopic kidneys. Although further studies are needed, this minimally invasive approach likely provides analgesic and accelerated recovery benefits compared with the open approach.

SUMMARY

The main points of interest of this chapter are summarized below.

- (1) Horseshoe kidney is the most common congenital renal anomaly and has an incidence of 0.25% in the population.
- (2) Pelvic ectopia occurs in 1 of 2100–3000 autopsies and accounts for the majority of ectopic kidneys.
- (3) Most pelvic and horseshoe kidneys are clinically asymptomatic although nephrolithiasis, ureteropelvic junction obstruction, and renal masses are the most common indications for surgery in congenitally abnormal kidneys.
- (4) Numerous studies have successfully reported laparoscopic pyeloplasty in horseshoe kidneys.
- (5) The most common indications for heminephrectomy in a horseshoe kidney are non-functioning moiety and renal mass.
- (6) Regarding heminephrectomy for a horseshoe kidney, various techniques have been described for dividing the isthmus.
- (7) Shock wave lithotripsy, ureteroscopy, or laparoscopic assisted percutaneous nephrolithotomy can be considered in the management of calculi in a pelvic kidney.
- (8) Standard percutaneous nephrolithotomy in the prone position is not possible for a pelvic kidney due to the intervening bony pelvis. Bowel mobilization and direct visual guidance laparoscopically aids the safe placement of a percutaneous tract while the patient is in supine position.
- (9) Laparoscopic pyeloplasty has also been successfully reported in pelvic kidneys.

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21 Ureteral substitution

James C Ulchaker and Bashir R Sankari

Ureteral substitution is a difficult technical procedure surgically, no matter what the type, and is fraught with potential complications. The vast majority of these procedures are performed in children; however, challenging issues exist when these problems occur in adults. Currently, there are no great options for ureteral substitution; however, extensive basic science and translational research is being undertaken to rectify this problem. Herein, we describe the current approaches to ureteral substitution and discuss the potential future options on the horizon.¹

The location of the ureteral injury and the length of the defect dictate the type of reconstructive surgery used. Injuries to the lower ureter can usually be repaired with direct ureteral reimplantation in the bladder alone or with a combination of a psoas hitch procedure. Injuries to the mid-ureter may require the addition of a Boari bladder flap or direct ureteroureterostomy if the injured ureteral segment is short. Injuries to the upper ureter may require a transureteroureterostomy. Complete ureteral injury will necessitate an ileal loop ureteral interposition or autotransplantation.²

Common surgical approaches to the ureter include subcostal incision for the upper ureter, Gibson lower quadrant incision for the mid-ureter, and a low midline or Pfannensteil incision for the lower ureter. A midline incision may be required if other body system injuries have also occurred.³

When a ureteral injury, either from trauma, iatrogenically, or from another cause occurs deep in the pelvis, the first thing one should consider is proper mobilization of the bladder to gain ureteral length, and subsequently shorten the ureteral length needed to obtain ample length to provide a tension-free ureterovesical anastomosis. One can often make up considerable distance solely with mobilization of the lateral, posterior, anterior, and dome aspects of the bladder to allow the ureteral length to be sufficient to enable a proper tension free anastomosis. When this mobilization is not sufficient, proximal ureteral mobilization may gain additional ureteral length. One should maintain as much peri-ureteral tissue as possible during dissection to preserve ureteral blood supply. The ureteral ends should be spatulated and reanastomosed using chromic, monocryl, or PDS suture using either an interrupted or



Figure 21.1 Spatulation of ureter using Metzenbaum scissors. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

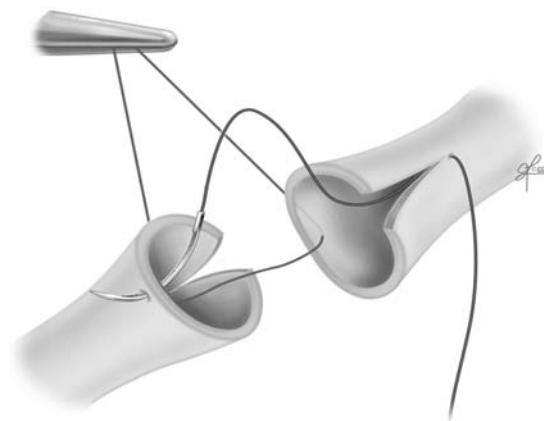


Figure 21.2 Reanastomosis with initial suture placement at corners. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

continuous technique (Figures 21.1–21.3). A JJ stent is placed after suturing of the backside of the ureter has been completed. Omental wraps, if physically available, can also be wrapped around the anastomosis.

A ureteroneocystostomy is best indicated for missing segments of the distal ureter. The bladder musculature is incised and the anastomosis is performed using a 5-0 suture over a JJ stent. Tunneling of the dome of the ureter can also be performed if a non-refluxing ureter is desired.

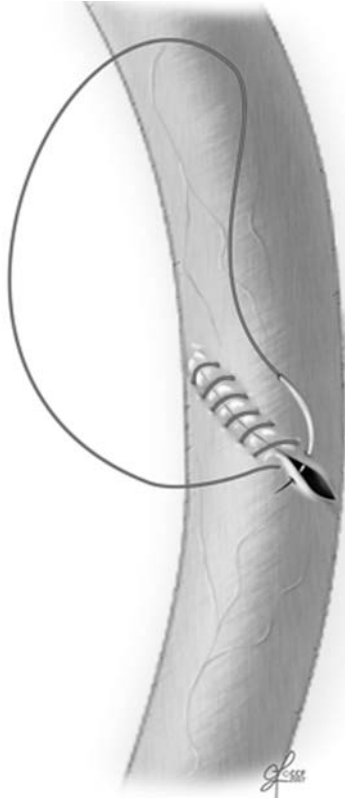


Figure 21.3 Completed ureteral reanastomosis. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

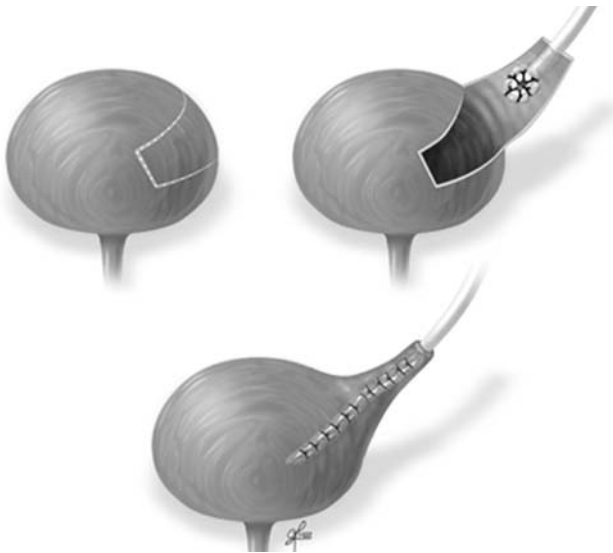


Figure 21.4 Boari flap with completed tubularized segment. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

A psoas hitch can be used to provide even more length if needed. This technique completely mobilizes the bladder to provide an additional 5–7 cm of length.

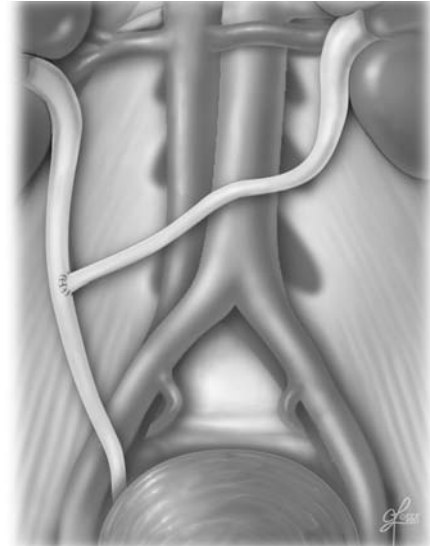


Figure 21.5 Transureteroureterostomy with left ureter anastomosed to mid-right ureter. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

Structures which may have to be divided include the contralateral superiovesical artery, the round ligaments in females, and the vas deferens in males. The ureter is anastomosed to the superior lateral aspect of the bladder dome using interrupted 4-0 or 5-0 sutures. The ipsilateral dome is then fixed to the psoas muscle using several interrupted 2-0 or 0 PDS sutures. One must avoid injury to the genitofemoral nerve when placing the sutures through the psoas fascia. A JJ stent is placed and the bladder is closed in multiple layers.

Anterior bladder wall flaps, known as Boari flaps, can be used to gain significant ureteral length (Figure 21.4). In this procedure, the ipsilateral superior vesical artery is identified and the pedicle flap is based on this blood supply. A U-shaped full-thickness pedicle flap is created with the width of the flap being at least three to four times the diameter of that of the ureter. The key to the procedure is to ensure that the flap is secured to the psoas muscle with a number of interrupted absorbable sutures to ensure stability. The flap is closed anteriorly and rolled into a tube using two layers of absorbable sutures.

Transureteroureterostomy remains an option for unilateral ureteral issues involving the distal half of a problematic ureter. This remains an uncommon approach but must be considered when immediate ureteral repair remains an option (Figure 21.5). In this approach, the colon on the side of the donor ureter is reflected and the native ureter with its surrounding periureteral tissue is carefully dissected. In left to right procedures, the ureter is passed above the level of the inferior mesenteric artery to prevent acute angulation

at this level. The posterior peritoneum is then incised over the recipient ureter and the ureter is dissected. A ureterotomy is then created in the recipient ureter, the donor ureter is spatulated, and stay sutures using a 5-0 suture, either chromic or PDS, are placed in the apex of the recipient ureterotomy and in a corresponding position in the end of the donor ureter. The posterior wall is anastomosed first, a JJ stent is inserted once the back wall anastomosis has been completed, and the anterior wall anastomosis is completed. The posterior peritoneum is then closed and the colon is returned to its proper anatomic position.

When one ureter is grossly abnormal, and the other is either normal or only moderately dilated, a satisfactory ureteral diversion can be performed using the grossly dilated ureter as the stoma and anastomosing the less dilated ureter obliquely end-to-side.

Both early and late complications follow cutaneous ureterostomies. The most serious early complication is necrosis of the ureterostomy stoma. This may result from excessive mobilization, which can interfere with the blood supply of the ureter; from too tight an opening of the abdominal wall muscle or skin; or from eversion of the ureter to form the stoma. Late complications of the cutaneous ureterostomy include stomal stenosis and stomal retraction. The long-term results with cutaneous ureterostomies have been disappointing.

When this is not possible for a variety of different reasons, such as, prior radiation therapy, diffuse fibrosis, or extensive adhesions, other modalities may be required to complete urinary integrity and eliminate urinary extravasations.

The use of ileal segments incorporated into the urinary system is used in many forms, and many ways in the urinary tract.⁴ When possible, an ileal ureter can be created to replace the damaged native structure. The ileal segment is maintained on its vascular pedicle, tapered appropriately on both its proximal and distal ends to allow for a well approximated ureteropelvic to ileal segment and distal ileal segment to bladder anastomosis. Proper stenting and drainage should be maintained to allow for proper tissue healing.

An end-to-end anastomosis is then performed between the renal pelvis and the proximal ileal segment, and a nephrostomy tube is inserted. A JJ stent is inserted, and the distal ileal segment is anastomosed to

the posterior wall of the bladder in a full-thickness two layered closure. An outer reinforcing layer of interrupted seromuscular tissue is performed last to ensure stability. A large sized Foley catheter is placed in the bladder, drains are placed, and all tubes are maintained for a minimum of 1 week. Both a nephrostogram and cystogram are performed to ensure collecting system integrity before any tubes are removed. This procedure is reserved only for when complete ureteral damage has occurred.

When the simplest option is clinically indicated an ileal conduit may be performed. This allows the ureters to drain into a wide channel conduit; however, an external stoma is required and potentially may decrease the quality of the patient's life, especially in younger individuals. An ileal segment of 20–25 cm is mobilized and harvested 15–20 cm proximal to the ileocecal valve. Bowel continuity is restored with a stapled side-to-side enteric anastomosis. The isolated ileal segment is then positioned posterior to the newly created bowel anastomosis in an isoperistaltic fashion. The ureters are then anastomosed to the newly created ileal segment in an end-to-side fashion using 5-0 chromic or PDS sutures. A stoma rod, stoma Foley, and 7 × 90 J stents are placed.

Renal autotransplantation can also be used in cases of complete ureteral destruction or disease. The kidney is removed and transplanted in the ileal fossa using standard transplant techniques.

Ureteral complications, be they from trauma or iatrogenic sources, are better avoided. However, most can be corrected with one of the above surgical procedures. One must consider all alternatives before a definitive procedure is undertaken.

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22 Retroperitoneal fibrosis

Alison M Lake and J Stuart Wolf Jr

Retroperitoneal fibrosis (RPF) was first reported in the literature in 1905 by the French urologist Alberran.¹ However, its first moniker was Ormond's disease, after Dr John Kelso Ormond described two patients with the disease in the 1948 issue of the *Journal of Urology*.² Other names include periureteritis fibrosa, periureteritis plastica, chronic periureteritis, sclerosing retroperitoneal granuloma, and fibrous retroperitonitis. The classic presentation is a middle-aged patient with subacute back or abdominal pain, constitutional symptoms and localized dysfunction in the urinary, gastrointestinal, and arterial or venous vascular systems. A benign fibrous and inflammatory retroperitoneal mass is the culprit.

RPF is a rare disease. The incidence is estimated between 1:200 000 and 1:500 000 per year worldwide.³ RPF has a 2:1 male-to-female predominance and occurs most often in patients 40–60 years of age.⁴ However, the disease has also been reported in pediatric and older adult populations.^{5–7} While sporadic reports of twin and sibling cases exist, there is no strong evidence of familial clustering.^{8,9} There is no racial preponderance of RPF.

CLINICAL PRESENTATION AND DIAGNOSTIC EVALUATION

The disease presentation is often insidious. Early symptoms are varied and non-specific. The classic pain is vague, poorly localized, and constant in a girdle distribution, beginning in the flank and lumbar area, and radiating to the lower abdominal quadrants and groin. Typically, patients find pain relief from aspirin, while narcotics prove less effective. Symptoms can be categorized as local or systemic and are remarkably similar for both the idiopathic and secondary forms. In addition to the characteristic pain, local symptoms include claudication and lower extremity edema (likely due to extrinsic compression of vasculature by the mass) which may lead to deep venous thrombosis; testicular pain, varicocele, and/or hydrocele (as a consequence of gonadal vessel involvement); constipation and rarely small bowel obstruction;^{10,11} ureteral and/or renal colic (from

extrinsic ureteral compression); jaundice in one case report (as a result of biliary obstruction);^{12,13} and localized urinary symptoms such as hematuria, polyuria, recurrent urinary tract infections, or oliguria. Systemic complaints include mild pyrexia, malaise, myalgias, nausea, vomiting, anorexia, and weight loss.

Any findings on physical examination are usually non-specific and unrevealing. This accounts for the frequency of delayed diagnosis. Many patients in the early stages may be hypertensive. Abdominal and lumbar or costovertebral angle tenderness may be present. A palpable or pulsatile abdominal mass or periumbilical bruit may indicate an associated aortic aneurysm. Non-specific signs and symptoms leading to diagnosis in the later stages of retroperitoneal fibrosis may account for the prevalence of ureteral involvement, which is estimated to occur in 80–100% of cases and is usually bilateral.^{14,15}

The work-up for RPF may occur when a patient presents with the aforementioned non-specific symptoms, but often does not occur until signs and symptoms of uremia are present. Laboratory values are relatively unrevealing. Elevated creatinine may indicate chronic renal failure due to extrinsic ureteral obstruction from the fibrotic retroperitoneal mass and interference with peristalsis. Erythrocyte sedimentation rate and C-reactive protein levels are elevated in upwards of 80% of RPF patients, indicating chronic inflammatory disease.^{15–17} These two inflammatory markers are often used to monitor the activity of disease, although they are not always reliable indicators.¹⁸ Anti-nuclear antibody (ANA) levels may also be elevated.^{14,19,20} Other less common laboratory abnormalities include anemia, a mild leukocytosis, and eosinophilia. A urinalysis is usually unremarkable, but may demonstrate hematuria or findings consistent with infection depending on the degree of urinary tract involvement.^{14,21}

Because clinical signs and symptoms and laboratory tests are non-diagnostic, the diagnosis of RPF is primarily made via imaging studies. Commonly used modalities include excretory urography (intravenous pyelogram [IVP]), computed tomography (CT), magnetic resonance imaging (MRI), and ultrasonography. In patients with normal kidney function, an IVP or CT

urogram may demonstrate the classic medially deviated ureters with proximal hydronephrosis. The process is usually bilateral. Both CT and MRI should demonstrate a large, flat mass on the anterior and lateral sides of the aorta, often encircling the inferior vena cava (see Figures 22.1 and 22.2).^{22,23} This mass is similar in attenuation to skeletal muscle.^{24–26} CT and MRI also provide a means of assessment for other processes such as primary malignancy, lymphadenopathy, vascular aneurysm, etc. Advantages of MRI over CT include avoidance of nephropathy-inducing contrast in a patient who may already have renal insufficiency. In addition, an inhomogeneous signal on T2 weighted images is suggestive of an underlying malignant process, but may also represent edema in a benign lesion.^{27–29} Ultrasonography is often the first imaging modality employed when investigating obstructive uropathy as a possible cause in a patient with renal insufficiency. It offers the advantages of imaging without contrast and without radiation exposure. Visualization of an indistinct, homogeneous, hypoechoic or echo-free retroperitoneal mass as well as hydronephrosis is common.²⁵ Limitations of ultrasound include body habitus, bowel gas, and adjacent bony structures that may obstruct the view.

As it most commonly presents in the later stages with symptoms of obstructive uropathy, the differential diagnosis of RPF must include other causes of renal obstruction. Other conditions in which retroperitoneal masses may be observed include malignancy such as lymphoma or sarcoma, infection such as tuberculosis, inflammatory pseudotumor, and retroperitoneal fibromatosis.^{30,31}

Many patients have associated autoimmune conditions which may present synchronously or metachronously with their RPF. A list of these conditions can be found in Table 22.1. Those patients afflicted by associated thyroid disease may suffer from Hashimoto's thyroiditis,^{15,32–34} Riedel's thyroiditis,³⁵ or Grave's disease.³³ Associated types of vasculitis include Wegner's granulomatosis^{36,37} and polyarteritis nodosa.³⁸ Multifocal fibrosclerosis is a group of autoimmune disorders which includes RPF, Riedel's thyroiditis, orbital pseudotumor, mediastinal fibrosis, and sclerosing cholangitis. This is a complex systemic fibroinflammatory syndrome with involvement of multiple organ systems.^{35,39,43}

The idiopathic form of the disease accounts for approximately two-thirds of the cases,^{21,44} while the other cases are the result of secondary causes such as medications, radiotherapy, infections, neoplasm, or surgery. A list of inciting factors of secondary RPF can be found in Table 22.2.^{45–58}



Figure 22.1 CT images demonstrating the typical appearance of a retroperitoneal mass of idiopathic retroperitoneal fibrosis. Notice that the mass is similar in attenuation to skeletal muscle.

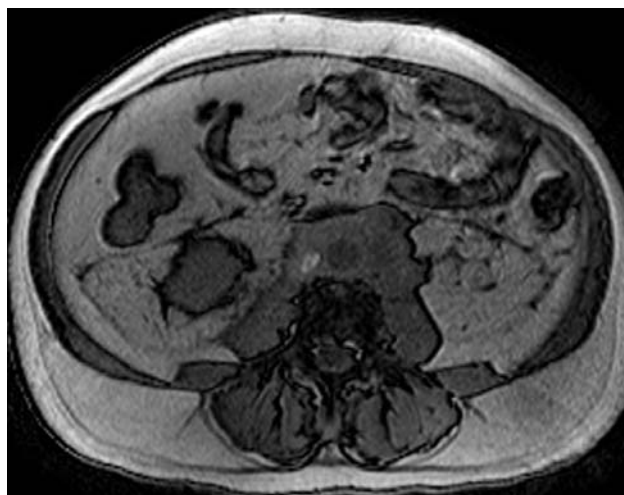


Figure 22.2 MRI image demonstrating the typical appearance of idiopathic retroperitoneal fibrosis.

Table 22.1 Conditions associated with retroperitoneal fibrosis

Ankylosing spondylitis
Autoimmune thyroid disease
Glomerulonephritis
Primary biliary cirrhosis
Rheumatoid arthritis
Systemic lupus erythematosus
Uveitis
Vasculitis
Multifocal fibrosclerosis
Riedel's thyroiditis
orbital pseudotumor
mediastinal fibrosis
sclerosing cholangitis

Table 22.2 Causes of secondary retroperitoneal fibrosis

<i>Medications</i>
Analgesics
Beta-blockers
Bromocriptine
Ergotamine
Hydralazine
Methyldopa
Methysergide
Pergolide
<i>Malignancy</i>
Breast
Carcinoid
Colon
Lymphoma
Prostate
Sarcoma
Stomach
<i>Surgery</i>
Colectomy
Hysterectomy
Lymphadenectomy
Repair of aortic aneurysm
<i>Infection</i>
Actinomycosis
Histoplasmosis
Tuberculosis
<i>Trauma</i>
Retroperitoneal bleed
Ruptured abdominal organ
Urine extravasation
Radiotherapy
<i>Miscellaneous</i>
Amyloidosis
Erdheim-Chester disease
Histiocytosis

PATHOGENESIS AND PATHOLOGY

In the leading theory for the pathogenesis of RPF, Mitchinson and Parums suggest RPF is a local inflammatory reaction to aortic atherosclerosis and falls under the umbrella of diseases encompassed by chronic periaortitis. This range of diseases is characterized by advanced aortic atherosclerosis, medial thinning, and pronounced adventitial and periaortic inflammation and fibrosis. They suggest that these sequelae are the consequence of local inflammation in reaction to substances often found in the atherosclerotic plaques of the abdominal aorta, such as oxidized low-density lipoproteins (LDL) and ceroid (a product of LDL oxidation within plaque macrophages). Evidence for this mechanism results from the study of chronic periaortitis patients in whom observations include activated B and T lymphocytes in the media and adventitia, high levels of interleukins in aortic wall sections, and circulating antibodies to oxidized LDL.^{59–61}

A second theory of pathogenesis is that RPF is a local manifestation of a systemic autoimmune disease.¹⁹ The presence of constitutional symptoms and the elevated concentrations of acute phase reactants lend support to this mechanism.^{15–17} In addition, many RPF patients have associated autoimmune diseases as previously mentioned and have autoantibodies present in their serum.^{32–38,62,63}

Other possible causes include antibodies to fibroblasts, a variant of large vessel vasculitis, and the presence of IgG4-producing plasma cells.^{64–66} In addition a genetic component may play a part, with a possible link to the human leukocyte antigen (HLA)-DRB1*03 allele⁶⁷ which is also linked to other autoimmune processes such as type 1 diabetes mellitus, systemic lupus erythematosus, and myasthenia gravis.

It is likely that the actual pathogenesis is a combination of many external and internal factors.

On gross examination the RPF plaque is a smooth, flat, hard mass of varying thickness that is tan to white in color, typically surrounding the abdominal aorta and common iliac vessels. It regularly extends to surround the ureters and inferior vena cava, and it usually originates between the origin of the renal arteries and the aortic bifurcation.⁴ However, it may rarely extend cephalad to involve the thoracic aorta,⁶⁸ anteriorly to include the mesenteric root or duodenum,¹¹ and posteriorly to involve the spinal cord.⁶⁹ Presacral extension is not uncommon. Atypical locations of the plaque have been described, including pelvic, peripancreatic, periureteral, or near the renal hilum.^{19,28} These

masses require tissue biopsy and microscopic analysis for diagnosis.

Microscopic examination of an RPF plaque reveals sclerosis and inflammation with infiltration of mononuclear cells in varying proportions, depending on disease stage. In later stages of the disease as well as at the core of the plaque, sclerosis and fibrosis predominates. An active chronic inflammatory infiltrate of eosinophils, macrophages, plasma cells, and lymphocytes is more characteristic of early disease stages and the infiltrating margins of the mass.⁷⁰

Although in the current setting, diagnosis is primarily by imaging, the gold standard for diagnosis is biopsy. There are no definitive guidelines for the need to biopsy to confirm diagnosis. However, biopsy should be strongly considered if a mass is atypical, surgery is planned anyway, other diagnostic tests suggest an underlying malignancy, and the patient does not respond to initial medical therapy. Adequate tissue for diagnosis may be achieved via either CT-guided core needle biopsy or biopsy by surgical excision. Inadequate specimen for diagnosis in core needle biopsy is an indication for surgical biopsy.

TREATMENT

The goals of medical therapy of treatment for RPF are to alleviate symptoms and relieve obstruction of retroperitoneal structures, to halt fibroinflammatory disease progression, and to induce disease remission and prevent recurrence or relapse. Given the rare nature of this disease, clinical trials are absent and the ideal therapy is unknown. In those cases with significant ureteral involvement and urinary tract obstruction, surgical treatment by ureterolysis has traditionally been the primary treatment (see the chapters *Management of the Ureteral Deficit* and *Laparoscopic Ureteral Surgery*). However, medical therapy is appropriate in many cases, particularly in those patients where ureteral obstruction is less severe and no significant renal dysfunction is present. It is important to realize that optimal management sometimes requires temporary measures to alleviate ureteral obstruction, such as drainage by percutaneous nephrostomies or ureteral stents, while medical therapy takes effect.

Corticosteroids are the mainstay of medical therapy. The absence of randomized controlled trials leaves the optimal dosage and duration of treatment unknown. Typically, patients are started on high dose steroids (60–80 mg of prednisone) on a daily or every other day regimen. This high dose is usually continued for

1–2 months and then tapered to a dose of 5–10 mg/day, which is continued for 1–2 years.^{3,16,19}

While some case series suggest that up to 90% of patients respond to steroids alone,^{3,16,21} certain groups of RPF patients appear to respond better to steroid therapy, in particular, elderly patients or those with a large inflammatory component on biopsy. Steroid resistance may be a result of late stage disease with a large fibrous component. However, failure to respond to steroid therapy either clinically or radiographically within the first 6 weeks of treatment should prompt further evaluation with biopsy (or repeat biopsy) to confirm a correct diagnosis. In those patients in whom a diagnosis of RPF is reconfirmed, steroids may be continued for several months with or without the use of concurrent agents.

Medications that have been used in conjunction with steroids or in an effort to reduce the duration of treatment with high-dose steroids include immunosuppressive agents such as azathioprine, methotrexate, mycophenolate mofetil, cyclophosphamide, penicillamine, and cyclosporine. Azathioprine (typical oral dosing: 2.5 mg/kg daily for 3–6 months, then 1.5 mg/kg daily for an additional 6 months) and cyclophosphamide (orally: 2 mg/kg daily for 3 months, tapered off by 6 months; or intravenously: 1000 mg/m² monthly for 6 months) have been reported to achieve disease remission and regression, but carry with them the risk of severe toxicities.^{17,20,71,72} Successful therapy with azathioprine has been reported in the pediatric population.⁵ Success with combination therapy using either mycophenolate mofetil or cyclosporine plus steroids has also been reported.^{73–75} Again, randomized studies comparing the effectiveness and toxicities of these various therapies are absent.

Tamoxifen, a non-steroidal antiestrogen which has found success in the treatment of desmoid tumors, has been used in the treatment of RPF. This is based on the shared characteristic of fibroblast proliferation in both RPF and desmoid tumors. Several studies have demonstrated relative success in RPF with tamoxifen treatment (typical oral dose: 20 mg daily for 12 months, with or without steroid therapy), although follow-up was limited.^{76–81} Tamoxifen has relatively few side-effects and thus may prove to be a good alternative to steroids. The mechanism of action for tamoxifen in the treatment of RPF remains to be elucidated.

Currently, standard medical therapy is treatment with steroids with or without another medication. Often, a second medication is added to the treatment regimen once diagnosis has been reconfirmed in a steroid resistant patient. It is important to realize that

selection of medical therapy requires careful attention to potential side-effects of the various therapeutic alternatives. Most common are hematologic side-effects and increased risk of renal toxicity. In addition, while steroids may play a role in the treatment of secondary RPF, in certain underlying etiologies such as infection they are contraindicated. Secondary RPF should be treated first by addressing the underlying cause, with addition of adjunct therapies only as necessary.

After initiating medical therapy, patients are evaluated for resolution of clinical signs and symptoms, changes in laboratory values, and changes on radiography. Pain and constitutional symptoms often improve within a few days of beginning medical therapy. In addition, erythrocyte sedimentation rate and C-reactive protein values often demonstrate an initial dramatic decrease.^{3,21,82} Several weeks following therapy initiation, obstructive symptoms begin to improve and a typical diuresis may be observed.³ Resolution of other disease manifestations, such as hypertension, renal insufficiency, or anemia, depends on the amount of permanent renal damage.

Depending on the medical regimen initiated, patients should be seen initially 2–4 weeks following the start of therapy. Evaluation at this time includes any change in clinical symptoms, such as resolution of pain and constitutional symptoms. In addition, erythrocyte sedimentation rate, C-reactive protein level, and creatinine level can be checked initially and then followed regularly to gauge therapeutic response. Other laboratory tests should be followed as dictated by the specific toxicities of the medications being administered. After the first 3 months of therapy, laboratory values can be checked every 3 months or so as appropriate.

Sequential evaluation on imaging is also helpful to monitor therapeutic response. Serial CT scanning is indicated for documentation of changes in the retroperitoneal mass and response to medical therapy.^{3,83} Resolution of the retroperitoneal mass on imaging may be observed as early as a few weeks after initiating medical therapy.^{3,84} A CT scan, MRI, or other imaging at 1–2 months and then every 6–12 months is appropriate to evaluate changes in the retroperitoneal mass and degree of urinary tract obstruction.⁸⁵ If clinical symptoms or laboratory results indicate the need, imaging may be obtained sooner.^{3,85} Stable size or resolution of retroperitoneal mass on imaging can be used to guide duration of treatment. In a patient with good clinical response to treatment, a stable mass may indicate persistent fibrous scar that will not respond to further treatment. On MRI, high signal intensity on T2

weighted images corresponds with the early stage of fibrous formation as a result of hypercellularity and a large fluid content, while mature fibrosis shows low signal intensity on T2 weighted images.²⁸ Thus, a persistent mass is not a treatment failure.³ In such cases, one study has shown that fluorodeoxyglucose positron emission tomography (FDG-PET) scanning will reveal very little or absent FDG accumulation, suggesting inactive residual disease.⁸⁶

Once patients are stable and have discontinued therapy, follow-up every 1–2 years is still warranted due to the possibility of disease relapse.^{44,87}

PROGNOSIS

The overall outlook for RPF patients is good.^{21,88} True rates of response to medical therapy and of relapse are not available because most studies have limited follow-up. However, in one retrospective study mortality is less than 10%.³ Ureteral obstruction is estimated to recur in up to half of patients treated with surgery alone, and in only about 10% of those who also receive steroids.^{14,17} While recurrence after treatment usually occurs in the first year, it may occur substantially later.^{14,21,88}

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23 Endoscopic and open surgical management of ureteroceles and ectopic ureters

Una J Lee and Jeffrey S Palmer

Congenital anomalies of the ureters are common. Ureteroceles and ectopic ureters are two such conditions. These conditions may be diagnosed either prenatally or postnatally, and may lead to hydronephrosis, a non-functioning upper pole renal unit, and/or complete renal non-function. This chapter discusses the etiology, diagnosis, and endoscopic and open surgical management options for ureteroceles and ectopic ureters.

CLASSIFICATION, NOMENCLATURE, AND CLINICAL PRESENTATION

Ureteroceles

Classification

A *ureterocele* is a cystic dilatation of the terminal intramural portion of the ureter. Ureteroceles are classified into two categories. *Orthotopic* or *intravesical ureteroceles* are ureteroceles that insert within the bladder. An *ectopic ureterocele* inserts in an abnormal, usually caudal, anatomic location, extending to the bladder neck or urethra. The ureterocele may vary in size from a small cystic dilatation of the submucosal ureter to a large balloon-like structure that fills the bladder.

Intravesical ureteroceles are further classified as *non-obstructed* (a large orifice without obstruction) (Figure 23.1) and *stenotic* (an orifice with a narrowed or pin-point opening resulting in obstruction) (Figure 23.2). Extravesical ureteroceles are classified as *sphincteric* (extends into bladder neck and urethra, but orifice is located outside the bladder) (Figure 23.3), *sphincterostenotic* (an orifice that is both stenotic and distal to the bladder neck), *cecoureterocele* (extends into the submucosa of the urethra, which can result in urethral obstruction, but the large orifice is localized within the bladder) (Figure 23.4), or *blind ectopic* (a sphincteric type of ureterocele, but no ureteral orifice is present).

Incidence and epidemiology

The incidence of ureteroceles is approximately 1 in 4000 children.¹ Approximately 80% occur in females,² and most occur in Caucasians. Ureteroceles are found

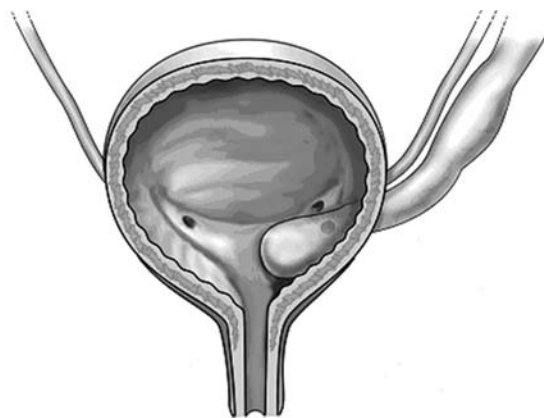


Figure 23.1 An intravesical non-obstructed ureterocele of a duplicated system.

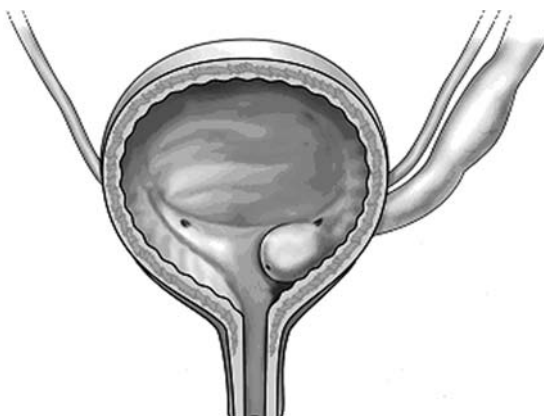


Figure 23.2 An intravesical stenotic ureterocele of a duplicated system with a pin-point ureteral orifice.

equally on the right and left side, with up to 10% of ectopic ureteroceles being bilateral.³ Ureteroceles may involve a single system. However, ureteroceles are most commonly seen in duplicated ureters, and usually involve the upper pole of a duplex system. Approximately 80% are associated with duplicated collecting systems.⁴ Single system ureteroceles are more common in males and adults.⁵

Etiology

There are several theories that potentially explain ureterocele development. One theory is that Chwalla's

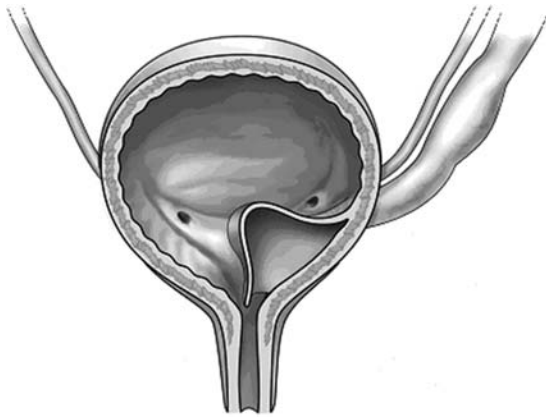


Figure 23.3 A sphincteric ureterocele.

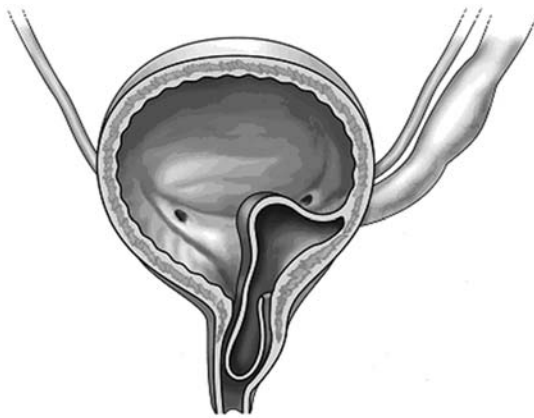


Figure 23.4 A cecoureterocele whereby it extends into the submucosa of the urethra, but the large orifice is localized within the bladder.

membrane, the membrane that temporally divides the urogenital sinus from the caudal end of the Wolffian duct, persists.⁶ Another theory postulates that there is inadequate muscular layer development of the distal ureter.⁷ Also, excessive dilatation of the distal ureter during development has been proposed to explain the etiology of ureterocele.⁸

Clinical presentation

Most commonly ureterocele are diagnosed by prenatal ultrasound. Fetal hydronephrosis is noted on prenatal ultrasound, and follow-up postnatal ultrasonogram and voiding cystourethrogram (VCUG) demonstrate the ureterocele. Ureterocele may also present during physical examination. An ectopic ureterocele may prolapse through the urethra and present as an introital mass in a girl (Figure 23.5). Children may also present with a urinary tract infection. Vesicoureteral reflux

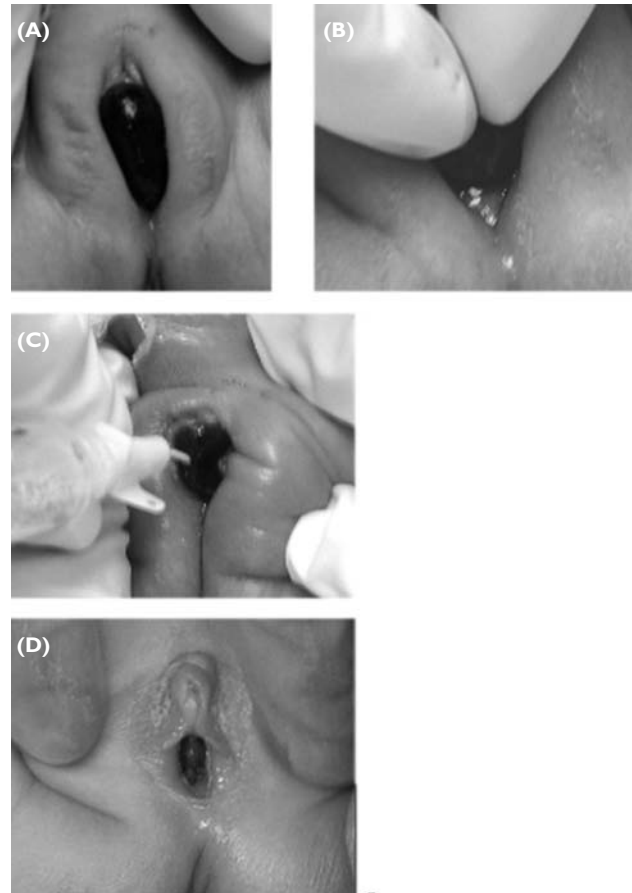


Figure 23.5 (A) Prolapsed ureterocele presenting as interlabial mass in a one month old girl (B) Presented as bulging, hemorrhagic membrane-like structure in vestibule, with associated obstruction of upper pole of complete duplex renal system. The vaginal orifice is visible and not included in the mass. (C) Insertion of angiocath into ureterocele (at bedside) with resulting reduction in size and relief of discomfort. (D) Marked improvement in the size of the ureterocele 3 days after drainage at bedside. Ureterocele is now visible only when spreading the labia. Patient proceeded to have endoscopic incision of ureterocele in the operating room.

occurs in up to one-half of ipsilateral lower pole ureters that are associated with ureterocele and may also be seen in the contralateral ureter.⁹

Ectopic ureters

An *ectopic ureter* is an abnormally located distal portion of the ureter. The urine drains into an orifice that is not in its proper location on the trigone of the bladder. The term 'ectopic ureter' is usually used to describe a ureter that terminates at the bladder neck or distally into one of the mesonephric structures.

Etiology

Ectopic ureters result from the abnormal development of the terminal portion of the mesonephric duct. During fetal development, ureteral budding is further cephalad than normal, delaying ureteral absorption in the bladder, resulting in ectopia.

Incidence and epidemiology

Ectopic ureters occur in 0.025% of the population.¹⁰ Ten per cent are bilateral. Ectopic ureters occur more frequently in females than in males by a ratio of 6 : 1. An ectopic ureter can occur in a non-duplicated collecting system but is more common in a duplicated system. In females, more than 80% of ectopic ureters drain duplicated systems. In males, most ectopic ureters drain a single system. Approximately 80% of all ectopic ureters drain the upper pole of a duplex kidney.⁹ In males, the ureters may terminate at the bladder neck/prostatic urethra (48%), seminal vesicle (40%), ejaculatory duct (8%), vas deferens (3%), or epididymis (0.5%). In females, the ureters may terminate at the bladder neck/urethra (35%), vestibule (30%), vagina (25%), or uterus (5%).¹¹ The more remote the ureteral orifice, the greater the degree of renal maldevelopment that is usually seen.¹²

Clinical presentation

If the ectopia is associated with obstruction, hydronephrosis may result, which may be detected on prenatal ultrasonography. Poor drainage can predispose children to urinary tract infections. Ectopic ureters may also be associated with vesicoureteral reflux.

The clinical presentation of ectopic ureters often differs by gender due to the differing terminating locations of the ureters. Ectopic ureters in girls may cause continuous incontinence since the ureter drains urine directly into or near the vagina. This problem becomes more apparent after toilet training. Girls may otherwise void normally, but have a constant dampness or moistness, due to the draining of urine distal to the bladder neck and urethral sphincter mechanism. In contrast, boys with ectopic ureters do not typically present with incontinence since the ectopic ureter drains proximal to the external urinary sphincter. In boys, an ectopic ureter can drain into other mesonephric structures including the seminal vesicles, vas deferens, epididymis, and prostatic urethra or ejaculatory duct. Prepubertal boys with a history of recurrent epididymitis should be evaluated for ectopic ureters. Postpubertal males with ectopic ureters most commonly present with complaints of chronic prostatitis and painful intercourse and ejaculation.

DIAGNOSTIC EVALUATION

Ureteroceles and ectopic ureters may arise from a single or duplicated collecting system. The diagnostic challenge is to determine which renal moiety is the origin of these congenital anomalies. This section reviews the diagnostic evaluation of suspect ureteral anomalies.

Ultrasonography

The initial radiographic imaging of choice for ureteroceles and ectopic ureters is ultrasonography with the majority of ureteroceles diagnosed using this modality. The ultrasonogram may have been performed as a follow-up test to hydronephrosis detected on prenatal ultrasonogram or part of the evaluation for a urinary tract infection. Ultrasonography can evaluate the presence and degree of hydronephrosis, as well as visualize a cystic mass at the intravesical distal end of the ureter, findings which are consistent with a ureterocele. A pseudoureterocele, an ectopic ureter displacing the bladder, may appear similar to a ureterocele.¹³ When reviewing the ultrasonogram, overdistention of the bladder needs to be assessed because this can collapse the ureterocele resulting in a normal appearing bladder. It is also important to evaluate for duplicated system(s), the amount and quality of the renal parenchyma (i.e. hyperechoic parenchyma reflecting dysplasia), and the contralateral kidney.

Voiding cystourethrogram

While a VCUG is less sensitive than ultrasonography for detecting a ureterocele, the presence of a ureterocele can usually be confirmed on the former test. Dilute contrast may allow better visualization of the ureterocele, which appears as a smooth filling defect located in the proximity of the trigone. As with ultrasonography, overdistention of the bladder needs to be assessed because this can collapse the ureterocele resulting in a normal appearing bladder. An ectopic ureter in the urethral sphincter may be obstructed during bladder filling and then reflux when the sphincter relaxes during voiding. A cyclic VCUG in which the bladder is imaged during several cycles of filling and voiding can be performed to evaluate for intermittent reflux.

Renal scintigraphy

A radionuclide renal scan is important to assess the function and drainage of the upper tracts.

Technetium-99m (^{99m}Tc)-diethylenetriaminepentacetic acid (DTPA) and mercaptoacetyl triglycine (MAG-3) provide renal function and drainage information, while (^{99m}Tc)-dimercaptosuccinic acid (DMSA) is a more an anatomic study evaluating for scarring. Ureterocele and ectopic ureters can be associated with a functioning upper pole. However, an upper pole associated with an ectopic ureterocele in a duplicated system usually has little or no function.

Intravenous urogram and cystoscopy

In more difficult cases, especially with ectopic ureters, when the anatomy is not completely delineated then an intravenous urogram (IVU) and/or endoscopy is indicated.¹⁴ The differentiation of non-functioning occult duplications may be better demonstrated with retrograde pyelograms while minimally functioning upper pole moieties may be differentiated with IVU. A 'drooping lily sign' is associated with an inferior and lateral displacement of the lower pole moiety by a non-functioning or minimally functioning upper pole moiety. A 'cobra head' is the appearance of a ureterocele at the ureterovesical junction on IVU. This renal and ureteral anatomic information will then assist in counseling parents on the treatment alternatives.

Cystoscopy and vaginoscopy allow the surgeon to clearly delineate the anatomy. Ureterocele with cystic dilation can be noted. However, small and extravesical type ureterocele may be more challenging to identify. Overfilling the bladder will decompress ureterocele resulting in the inability to adequately visualize them. Cystoscopy allows for evaluation of a duplicated collecting system with visualization of two ureteral orifices localized to one side of the trigone. Also, a retrograde pyelogram can be performed thereby clarify the anatomy of a duplicated collecting system. Cystourethroscopy along with vaginoscopy allows for the visualization of ectopic ureteral orifices. Although endoscopy requires anesthesia in the pediatric population, it does provide a significant amount of anatomic information.

Computed tomography and magnetic resonance imaging

Computed tomography (CT) and more recently magnetic resonance imaging (MRI) have been used to evaluate renal anatomy. The disadvantage of the former is the exposure to radiation in pediatric groups, while the latter requires sedation/anesthesia in the pediatric population. However, the information obtained is

better able to delineate ureterocele, ectopic ureters, and duplicated collecting systems.

MANAGEMENT

The management of ureterocele and ectopic ureters is based on several criteria. First, is the affected ureter(s) refluxing and/or obstructed? Second, is the affected ureter(s) associated with a single or duplicated collecting system? Third, is there function of the kidney or associated renal moiety? Fourth, is the ipsilateral lower pole ureter, contralateral ureter, and/or bladder affected? There are several approaches to each of the possible scenarios. Table 23.1 summarizes the management options.

Table 23.1 Flow chart for management of ureterocele and ectopic ureters.

Ureterocele

Single system

minimal or no function

→ nephrectomy

adequate function

→ endoscopic incision or puncture

Duplicated system

minimal or no function

→ upper pole heminephrectomy ± ureterocele excision ± ureteral reimplantation OR

→ endoscopic incision or puncture

adequate function

→ endoscopic incision or puncture OR

→ upper pole heminephrectomy OR

→ ureterocele excision ± ureteral reimplantation OR

→ upper to lower ureteroureterostomy or ureteropyelostomy

Ectopic ureter

Single system

minimal or no function

→ nephrectomy ± ureterectomy (obstructed/refluxing)

adequate function

→ ureteral reimplantation

Duplicated system

minimal or no function

→ heminephrectomy ± ureteral reimplantation (reflux)

function + obstruction (upper pole)

→ upper to lower ureteropyelostomy OR

→ upper to lower ureteroureterostomy

function + obstruction (upper pole) + refluxing (lower pole)

→ ureteropyelostomy with ureterectomy of upper pole ureter + ureteral reimplantation of lower pole ureter OR

→ ureteroureterostomy with ureterectomy of upper pole ureter + ureteral reimplantation of lower pole ureter

Management of ureteroceles

When a patient is diagnosed with a ureterocele, prophylactic antibiotics should be started and continued until resolution of the ureterocele. The main surgical indications to treat ureteroceles are relieving the obstruction, preservation of renal function, and prevention of infection. A contraindication to treatment is an acute untreated urinary infection. However, in cases of urosepsis, relieving the obstruction immediately is essential.

Expectant management

As an increasing number of ureteroceles are diagnosed as a consequence of the widespread use of prenatal ultrasound, the role for non-operative management has been explored in asymptomatic neonates with antenatally detected ureteroceles. This may be an option for select cases in which the ureteroceles are associated with non-obstructive and non-refluxing systems. However, patients should be maintained on antibiotics and followed with serial imaging studies to prevent progression of renal loss of function.¹⁵ Several case series describe expectant management indications and outcomes.^{16,17} Non-obstructed intravesical ureteroceles that remain asymptomatic may be candidates for this type of watchful waiting.¹⁸ Spontaneous resolution of ureteroceles has also been described.

Surgical treatment

There are several endoscopic, open, and laparoscopic surgical options to treat ureteroceles. The appropriate treatment depends on the patient's age and clinical presentation, as well as ureteral anatomy and renal function. The management of each patient is individualized due to the many clinical variables. In most cases, ureteroceles are detected prenatally, and surgical treatment in infancy is appropriate. Ureterocele location (orthotopic versus ectopic) as well as the function of the associated renal unit (none/poor function versus adequate/salvageable function) guide surgical management. The presence of single versus duplex systems is also an important factor in the decision making process. The presence of vesicoureteral reflux is also an important predictor of future surgery. When a patient does not have reflux, a definitive procedure should be considered.

Endoscopic incision of ureteroceles The treatment of the ureterocele is based upon relieving the obstruction and decompressing the collecting system (Figure 23.6). Historically endoscopic decompression was reserved for emergency cases of urosepsis. However, the role for endoscopic management of ureteroceles is expanding as

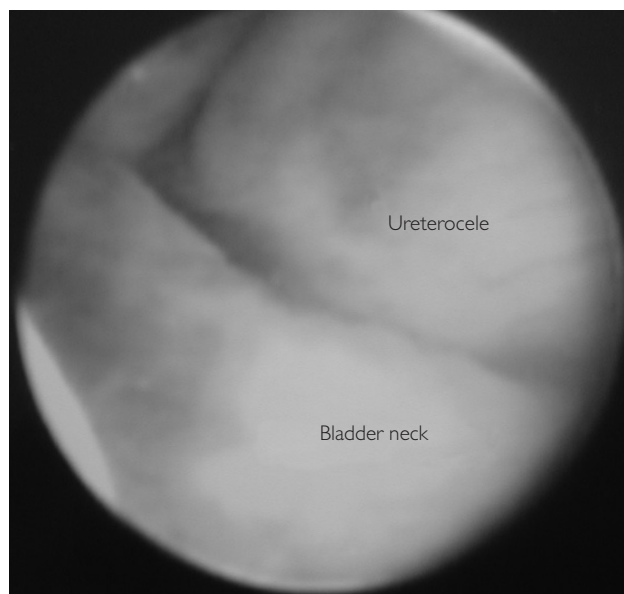


Figure 23.6 Cystoscopic view of a large ureterocele at the bladder neck.

this technique has resulted in favorable outcomes.¹⁹ Endoscopic decompression is the first line of treatment in single-system intravesical ureteroceles. Endoscopic incision of intravesical ureteroceles is a definitive treatment in 70–90% of these cases.²⁰ Thick walled ureteroceles require repeat endoscopic procedures more frequently than thin and intermediately thick walled ureteroceles.²¹ Intravesical ureteroceles have better outcomes than extravesical ureteroceles with higher rates of decompression (93% versus 75%), preservation of upper pole function (96% versus 47%), and need for secondary procedures (7% versus 50%) and a lower rate of newly created reflux (18% versus 47%).²² Approximately 50% of cases involving extravesical ureteroceles required subsequent surgery.²³ Ectopic ureteroceles, duplex systems, and vesicoureteral reflux are associated with increased reoperation rates.²⁴ Of patients with ureteroceles 30–50% will require an open bladder operation later in life due to a persistent ureterocele, diverticulum at the site of the ureterocele, or persistent lower pole reflux.²⁵ Therefore in patients where there is an increased incidence of these complications a primary open bladder approach may be appropriate.

The advantages of endoscopic ureterocele incision include that it is minimally invasive, requires a brief general anesthetic, and can generally be done as an outpatient procedure. Also, this procedure does not preclude future surgery with decompression of the dilated ureter actually facilitating subsequent surgery. An associated sequela of ureterocele decompression is the development of vesicoureteral

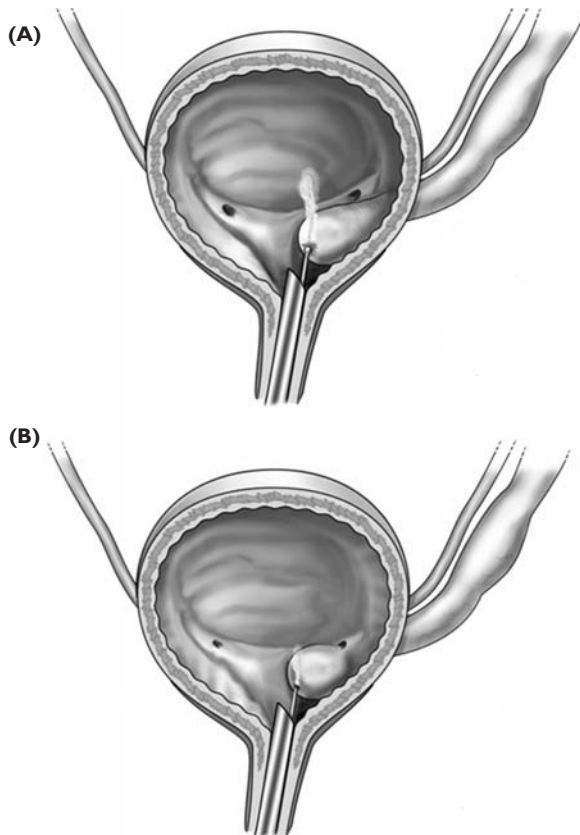


Figure 23.7 (A) Incision of ureterocele with bugbee electrocautery. (B) Incision of ureterocele with holmium:YAG laser.

reflux of the ipsilateral and/or contralateral ureter(s). If the infant has a non-functioning upper pole with no associated reflux, a primary heminephrectomy should be considered initially as it precludes the need for future bladder surgery.

Several techniques for endoscopic decompression have been used, including puncture with a stylet, cold knife incision, and incision with electrocautery.^{26,27} The electrocautery technique involves the use of a bugbee introduced through a pediatric cystoscope (Figure 23.7). With cutting current the bugbee is used to incise the ureterocele wall with a single puncture. The site of puncture is as caudal as possible within the bladder. This technique relieves the obstruction, and the roof of the ureterocele should collapse onto the floor of the bladder, acting as a flap valve mechanism to prevent reflux. An alternative technique involves holmium:YAG laser puncture, which has also been reported as a safe, effective method of decompression even in neonates.²⁸

Ureterocele excision and ureteral reimplantation Ureterocele excision with bladder reconstruction offers definitive management of the obstruction, bladder floor,

and associated vesicoureteral reflux. However, it can be technically challenging in young infants, and is reserved for patients with persistent reflux or obstruction after attempted initial treatment. The surgical exposure is identical to ureteral reimplantation. To excise the ureterocele, the epithelial floor of the ureterocele is excised preserving a cuff of bladder mucosa around the upper pole and lower pole urinary orifices. A common sheath ureteral reimplantation is then performed.

Nephrectomy Nephrectomy is the treatment of choice in a minimally or non-functioning single system. Open nephrectomy is usually performed through a flank incision. Laparoscopic nephrectomy can be performed through a transabdominal or retroperitoneal approach.²⁹

Upper pole heminephrectomy Heminephrectomy is an excellent surgical option in the management of ureteroceles associated with a non-functioning renal moiety. An upper pole heminephrectomy can be performed with or without lower tract reconstruction. In patients with no or low grade reflux, an upper pole heminephrectomy will decompress the system and likely be the definitive procedure.³⁰ In patients with high grade reflux into the ipsilateral lower pole ureter or contralateral ureter, there is a higher risk that the patient will need a secondary procedure, so a combined upper and lower tract surgery can address both issues during one operative setting. Another option, particularly for neonates, is a staged procedure. Upper pole heminephrectomy can be performed initially, and then the bladder reconstruction can be done later at a safer age.³¹

Open heminephrectomy is usually performed through a flank incision. Laparoscopic heminephrectomy can be performed through a transabdominal or retroperitoneal approach. The kidney is mobilized along with the proximal ureters. The upper pole ureter is dissected off the lower pole ureter and the former ureter is divided. The margin between the upper pole and lower pole of the kidney is divided with electrocautery, with care to avoid ligating accessory vessels to the lower pole. If injury to the lower pole collecting system occurs, then closure should be performed with absorbable suture. If a complete ureterectomy is performed it is accomplished through a second incision, typically a Pfannenstiel incision. However, if the heminephrectomy is performed laparoscopically, then the complete ureterectomy can be performed through the same port sites.

Ureteropyelostomy or ureteroureterostomy Ureteropyelostomy (upper pole ureter to lower pole renal pelvis) or ureteroureterostomy (upper pole ureter to

lower pole ureter) is the appropriate surgical management for ureteroceles when the upper pole has normal function. Since the upper pole supplies only one-third of the ipsilateral renal function, heminephrectomy is still a viable option in cases when ureteropyelostomy is technically difficult due to anatomic considerations.

To perform the anastomosis several principles should be followed. The anastomosis is usually positioned anterolaterally with traction sutures to assist with the anastomosis. Stenting and drain insertion is based on surgeon preference, although the former is usually not necessary.

Complications Complications of endoscopic incision are uncommon. They include ureterocele recurrence and de novo reflux.³² When bladder reconstruction is performed, one study found voiding dysfunction (infrequent voiding, large capacities, and significant postvoid residuals) in 22 of 33 patients who had ectopic ureteroceles excised and bladder reconstruction at a mean age of 10 months.³³ It is unknown whether the voiding dysfunction was due to the underlying congenital anomaly or a consequence of surgery.

Management of ectopic ureters

When a patient is diagnosed with an ectopic ureter as with ureteroceles, prophylactic antibiotics should be started. The surgical options are similar to those offered for ureteroceles (Figure 23.6). As in ureteroceles, a contraindication to treatment is an acute untreated urinary infection. However, in cases of urosepsis, relieving the obstruction immediately is essential.

Expectant management

Unlike ureteroceles, expectant management is less indicated in the management of ectopic ureters. Ectopic ureters typically obstruct, reflux, and/or lead to urinary incontinence.

Surgical treatment

Nephrectomy Nephrectomy is the treatment of choice in a minimally or non-functioning single system. Nephrectomy can be performed as an open or laparoscopic procedure with partial or total ureterectomy. One area of disagreement is the management of lower ureteral segments that drain into gynecologic structures.³⁴ Many advocate that distal ureterectomy is not necessary since ascending infections are uncommon. If the distal ureterectomy is performed, great care must be taken with the dissection of the most

distal segment due to possible association with the urinary sphincter mechanism.

Upper pole heminephrectomy Heminephrectomy is an excellent surgical option in the management of ectopic ureters associated with a non-functioning renal moiety. Heminephrectomy prevents the flow of urine into the ectopic ureter, thus preventing the associated incontinence or obstruction, and reducing the risk of infection. When an ectopic ureter is associated with a single collecting system, the associated kidney is usually dysplastic or poorly functioning. If the upper pole moiety is non-functional, a partial nephroureterectomy is performed and the upper pole ureter is removed to the pelvic brim. This can be performed by open surgery or laparoscopically. A second incision can be used to remove the ureteral stump.

When there is reflux associated with the renal unit, whether to perform a complete or partial ureterectomy is controversial due to concern regarding postoperative complications, including infections. Open heminephrectomy is usually performed through a flank incision. Laparoscopic heminephrectomy can be done through a transabdominal or retroperitoneal approach. As with complete ureterectomy associated with nephrectomy, care must be implemented with the most distal segment to prevent injury to the urinary sphincter mechanism.

Ureteropyelostomy or ureteroureterostomy In a duplex system when upper pole kidney function is adequate, a ureteropyelostomy (upper pole ureter to lower pole renal pelvis) or ureteroureterostomy (upper pole ureter to lower pole ureter) can be performed. In a ureteropyelostomy procedure, the ectopic ureter is divided near the kidney and sutured into the renal pelvis of the lower part of the kidney. The urine from the upper part of the kidney drains into the ectopic ureter. This procedure is an option when the upper pole renal moiety is functional. This operation has a slightly higher complication rate compared with other operations used to treat ectopic ureters.

Ureteral reimplantation The ectopic ureter is removed from its abnormal position and reimplanted into the bladder. This operation preserves all kidney tissue and treats and prevents vesicoureteral reflux. If the involved kidney is functioning well, the recommended treatment is ureteral reimplantation. In rare instances of bilateral single system ectopic ureters, bilateral ureteral reimplantation is performed. In patients with a functioning upper pole system and coexisting lower pole vesicoureteral reflux, a common sheath ureteral reimplantation is performed. Ureteral

tapering may be necessary and this can be performed through one of several techniques. As with distal ureterectomy, care with the dissection of the distal most ureter must be performed to prevent injury to the urinary sphincter mechanism.

Complications The most common technical complications of ureteral reimplantation are ureteral obstruction, persistent reflux, and diverticula formation. The other complications are discussed in the Ureterocele section.

SUMMARY

Ureteroceles and ectopic ureters are two congenital anomalies that have several diagnostic and management approaches. Prenatal ultrasonography has allowed for earlier diagnosis and treatment. The literature and personal experience, as in any urologic condition, are important in properly approaching these children.

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24 Laparoscopic ureteral surgery

Thomas HS Hsu and Tatum Tarin

INTRODUCTION

Laparoscopic surgery has become an integral part of urology in recent years, and its application to the ureter has become increasingly widespread. The principles of laparoscopic surgical approaches to pyeloplasty, pyelolithotomy, ureterolithotomy, retrocaval ureter, idiopathic retroperitoneal fibrosis, ureteroneocystostomy, and transureteroureterostomy in adult patients are discussed in this chapter.

LAPAROSCOPIC PYELOPLASTY AND PYEOLITHOTOMY

Laparoscopic pyeloplasty for ureteropelvic junction obstruction (UPJO) was first introduced in 1993.¹ Today, it has been developed as a viable minimally invasive alternative to open pyeloplasty and endopyelotomy. Compared with both open pyeloplasty and endopyelotomy, laparoscopic pyeloplasty is associated with greater technical complexity and a steeper learning curve. However, in the hands of experienced laparoscopists, this procedure has been shown to provide lower patient morbidity and faster convalescence, with the reported success rates matching those of open pyeloplasty (90% or higher).

The general indications and contraindications for a laparoscopic repair of UPJO are similar to those for either an endourologic or an open operative procedure. Indications to intervene include the presence of pain, progressive loss of renal function, and development of ipsilateral upper tract calculi or infection. The objective of the laparoscopic surgery is to provide a tension-free, watertight repair with dependent drainage.

Three different laparoscopic approaches for pyeloplasty have been described in the literature: the standard transperitoneal approach, retroperitoneal approach, and anterior extraperitoneal approach. For each laparoscopic approach, a dismembered Andersen-Hynes pyeloplasty or one of the non-dismembered methods such as Y-V plasty and flap pyeloplasty (Culp) identical to those described for the open surgery can be used.

The transperitoneal approach to laparoscopic pyeloplasty, which was first described by Schuessler et al¹

and Kavoussi et al,² has been the most widely used laparoscopic method due to its associated large working space and familiar anatomy. Prior to the transperitoneal laparoscopic procedure, cystoscopy with retrograde pyelography is first performed to define the anatomy, followed by placement of a ureteral stent. The patient is then placed in a lateral decubitus position, and laparoscopic access to the peritoneal cavity is obtained via either the Veress needle or open surgical (Hasson) method. Three to five laparoscopic ports are commonly placed after the establishment of carbon dioxide pneumoperitoneum. Generally, the umbilical port is for laparoscope use, and two additional working ports are placed: a 5 mm port at the midpoint between the umbilicus and the xiphoid, and a 12 mm port at the suprapubic location along the midline. After medial mobilization of the colon, the ureter is first identified and dissected in the cephalad direction, thereby achieving mobilization of the ipsilateral proximal ureter, UPJ, and renal pelvis. At this time, the relevant anatomy is carefully evaluated to determine the etiology of the UPJO, and the appropriate type of surgical repair is then selected. The general methods of laparoscopic surgical repair are identical to those described for open pyeloplasty (Figures 24.1 and 24.2). In the case of dismembered pyeloplasty, which is appropriate for crossing vessels, the renal pelvis is first transected above the UPJ, after which the lateral aspect of the proximal ureter is spatulated. Following transposition of both renal pelvis and proximal ureter to the opposite side of the crossing vessel, if present, the ureteropelvic anastomosis is completed with intracorporeal suturing techniques. Reduction pelvioplasty may be performed by excising redundant renal pelvic tissue and closing the pyelotomy laparoscopically. Laparoscopic suturing can be accomplished via either free-hand or with a semi-automated device (EndoStitch™, US Surgical, Newark, CT, USA). Either continuous running or simple interrupted suturing may be used in the dismembered pyeloplasty, typically with the 4-0 absorbable suture. A surgical drain is placed after the completion of the laparoscopic procedure. In general, fascial puncture defects from trocars that are 10 mm or greater need to be closed to avoid incisional hernia.

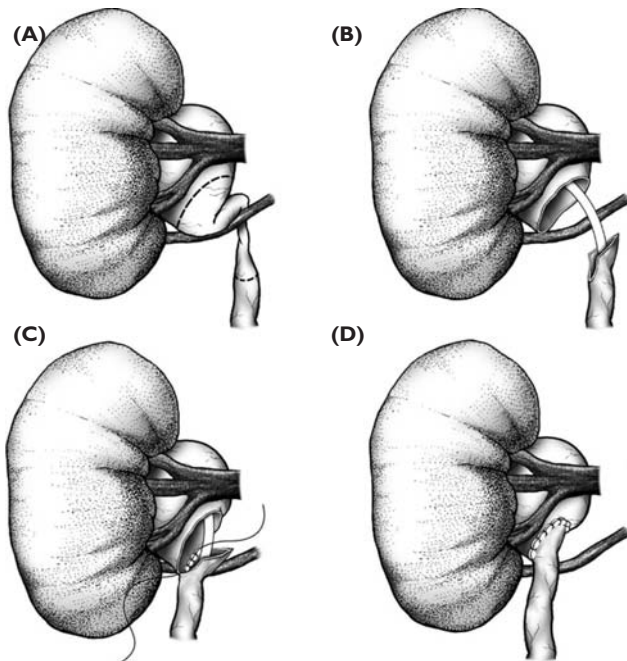


Figure 24.1 Dismembered pyeloplasty involving transposition of crossing vessel: (A) ureteropelvic junction obstruction secondary to an accessory lower pole vessel; (B) excision of ureteropelvic segment, after which the preplaced ureteral stent comes into view; (C) transposition of ureteral stent and proximal ureter anterior to the crossing vessel; and (D) completed ureteral anastomosis anterior to the crossing vessel. Courtesy of Dr Simon Kimm.

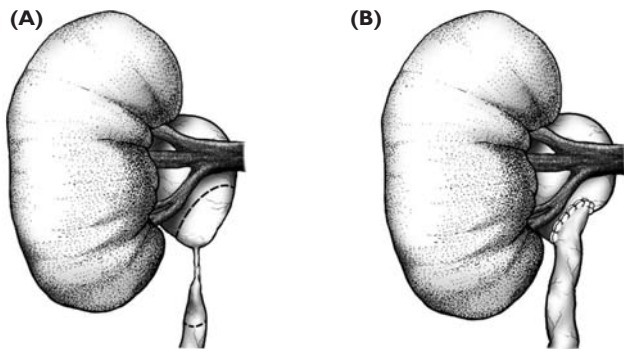


Figure 24.2 Dismembered pyeloplasty without crossing vessel: (A) ureteropelvic junction obstruction secondary to stricture; and (B) excision of ureteropelvic stricture followed by anastomosis. Courtesy of Dr Simon Kimm.

In the retroperitoneoscopic approach, which was first reported by Janetschek et al,³ cystoscopy with retrograde pyelography and ureteral stent placement is performed as discussed above. In this approach, the patient is typically positioned in a flank position on the operating table with elevation of the kidney rest. Following open access (Hassan) technique to enter the

retroperitoneum at the tip of the 12th rib, an adequate retroperitoneal working space can be created with balloon dilatation. Following carbon dioxide pneumoretroperitoneum, two additional laparoscopic ports are typically placed: a 10 mm port along the midaxillary line near the iliac crest and a 5 mm port at the angle of 12th rib and erector spinae. Ureteral dissection, mobilization, and subsequent UPJ repair are identical to those described for the transperitoneal approach above.

In the anterior extraperitoneal laparoscopic approach, first described by Hsu and Prest,⁴ cystoscopy with retrograde pyelography and ureteral stent placement is first performed as described above. The patient is then placed in a lateral decubitus position. Access to the preperitoneal space is achieved using open surgical techniques via a 1–1.5 cm incision at the lateral border of ipsilateral rectus muscle at the level of umbilicus, after which an adequate preperitoneal space is created with balloon dilatation. Following carbon dioxide insufflation, two additional laparoscopic ports are placed: a 10 mm trocar at the midpoint between the umbilical level and the lower edge of the rib cage, and a 5 mm trocar at the midpoint between the umbilical level and the upper border of the pubic bone. An additional 5 mm port along the anterior axillary line at the level of the umbilicus may be placed for retraction purposes. Following port placements, the boundary between the retroperitoneal fat and peritoneal sac is first identified and developed, which allows medial mobilization of the peritoneal sac containing the bowel contents en bloc. The anterior aspects of the retroperitoneal structures including the ipsilateral ureter and kidney then come into view. The subsequent steps including ureteral dissection and UPJ repair are identical to those discussed in the transperitoneal laparoscopic pyeloplasty. At the conclusion of the extraperitoneal procedure, a surgical drain is similarly placed, and all 10 mm fascial defects are closed as discussed previously.

Following laparoscopic pyeloplasty, a clear liquid diet is typically initiated on postoperative day 1 and advanced appropriately. The urethral Foley catheter is usually removed 24–36 hours postoperatively, and the surgical drain is removed within 1–2 days after Foley removal if the drain output remains negligible. The ureteral stent is usually removed 4–6 weeks postoperatively, and further follow-up including the use of diuretic renal scan or other imaging studies is performed as for any open pyeloplasty.

Most of the published laparoscopic pyeloplasty reports involve the classic Andersen-Hynes dismembered technique.^{5–9} The great majority of the patients

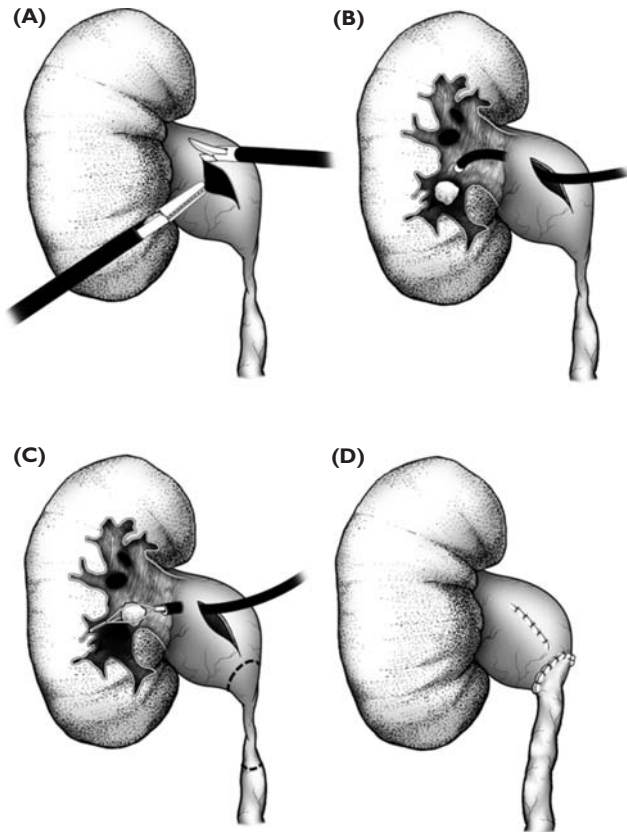


Figure 24.3 Laparoscopic pyeloplasty with concomitant pyelolithotomy: (A) pyelotomy creation; (B) placement of flexible cystoscope into collecting system to identify the stone; (C) basket extraction of the stone; and (D) completion of laparoscopic pyeloplasty and pyelotomy closure. Courtesy of Dr Simon Kimm.

in these recent series underwent primary laparoscopic pyeloplasties. The reported mean operative times are in the range of 119–252 minutes. In the hands of experienced laparoscopists, the entire surgical procedure can be consistently performed within 3.5 hours.⁹ Perioperative complication rates are generally low, in the range of 2–12%. Open conversion rates are also low overall, in the range of 0–5%. Perioperative blood transfusion risk is usually low, and postoperative analgesic use is generally minimal. Mean hospital stay length ranges from 2.6 to 4.5 days. With mean follow-up times of 14–26 months, the reported rates of surgical success are in the range of 87–99%.

Presence of concomitant calculi in the setting of UPJO can be managed laparoscopically with success (Figure 24.3). Recently, Ramakumar et al reported 20 cases of laparoscopic pyeloplasty with concomitant pyelolithotomy.¹⁰ In the series, extraction of the calculi was performed with the use of a flexible cystoscope introduced through a 10–12 mm port site.

With a mean follow-up of 3 months, 90% of the patients were stone free, and 90% of the patients had patent UPJ radiographically.

LAPAROSCOPIC URETEROLITHOTOMY

The management of ureteral stones has significantly evolved over the past two decades and has shifted from open surgery to less invasive procedures including extracorporeal shock wave lithotripsy, percutaneous lithotripsy, and ureteroscopic lithotripsy. Despite these advancements, ureterolithotomy is still indicated in a small subset of patients. The primary role for ureterolithotomy is now limited to being the salvage therapy after failure of the first-line less-invasive treatments. However, this procedure should also be considered in patients with large, significantly impacted stones, ureteric anomaly, or high surgical risks in which single-session stone clearance would be beneficial.¹¹ Today, laparoscopic ureterolithotomy has been shown to provide an attractive and feasible alternative to open surgery in such a group of patients.

Laparoscopic ureterolithotomy can be performed via the transperitoneal or retroperitoneal approach. Transperitoneal laparoscopic ureterolithotomy was first reported in 1979.¹² In such an approach, the patient is usually placed in a lateral decubitus position after placement of a ureteral catheter up to the level of the stone. Transperitoneal access, carbon dioxide insufflation, and port placement are followed by bowel mobilization and ureteral dissection. The ureteral stone is identified, and the proximal part of the ureter may be occluded with endo-Babcock forceps or a vessel loop to prevent proximal stone migration. A longitudinal incision can be made with a laparoscopic blade, curved blade, or diathermy, and the stone is extracted using a stylet.^{11,13} For stones that are impacted but not adherent, a 5 mm spatula or a Fallopian tube holding forceps may be of use. The stone specimen may then be extracted using 10 mm cup forceps or, if the stone is too large, using a sponge holding forceps passed directly through the abdominal incision with gauze packing to preserve the gas insufflation. Following removal of the calculus, the ureterotomy is then closed over a ureteral stent with absorbable sutures laparoscopically. A surgical drain is left in place at the end of the surgery.

In the retroperitoneal approach, the procedure is similar to that in the transperitoneal case except patient positioning, in which a full flank position with kidney rest elevation is used. Access to the retroperitoneal

space is achieved at the tip of the 12th rib using the open surgical (Hassan) technique, as in other retroperitoneoscopic renal procedures. Two additional trocars are usually placed following retropneumoperitoneum. Ureteral dissection, stone identification, ureterotomy creation, stone extraction, ureterotomy closure over a stent, and surgical drain placement are similar to those described in the transperitoneal approach above. The retroperitoneal approach avoids urine spillage into the peritoneal cavity. However, surgical dissection and suturing may be more challenging due to the more limited working space.

Following laparoscopic ureterolithotomy, a clear liquid diet is typically initiated on postoperative day 1 and advanced appropriately. The urethral Foley catheter is usually removed 24–36 hours postoperatively, and the surgical drain is removed within 1–2 days after Foley removal if the drain output remains negligible. The ureteral stent is usually removed 4 weeks postoperatively, and further follow-up including the use of diuretic renal scan or other imaging studies is performed as for any open ureterolithotomy.

Both transperitoneal and retroperitoneal laparoscopic ureterolithotomies have been described to provide satisfactory stone clearance and clinical outcomes. Gaur et al reported one of the largest case series on such a topic.¹¹ In the study, 101 patients underwent retroperitoneoscopic ureterolithotomy. The mean stone size was 16 mm, with 75 located in the upper ureter, 11 in the mid-ureter, and 15 in the lower ureter. Retroperitoneal laparoscopic ureterolithotomy was successful in 93 patients with eight failures attributed to early experience and retroperitoneal fibrosis. Mean operative time was 79 minutes, and estimated blood loss was 25 ml. In this series, no patient required morphine for analgesia, and mean hospital stay was 3.5 days.

LAPAROSCOPIC MANAGEMENT OF RETROCAVAL URETER

Persistence of the lumbar segment of the subcardinal vein results in the formation of retrocaval ureter (also described as the circumcaval ureter or preureteral vena cava). Anatomically, only the right ureter is affected, and the retrocaval segment is located posterior to the vena cava. The retrocaval ureter can either encircle the vena cava by crossing it ventrally from medial to lateral before reaching the bladder or simply lie dorsal to the cava for a segment without wrapping around the cava completely and end in the bladder distally. In both variations, the retrocaval ureteral segment is susceptible to

proximal urinary obstruction as the ureter takes this tortuous ‘reverse-J’ or ‘S-shaped’ course down to the bladder. Surgical repair is indicated if there is evidence of flank pain or ipsilateral renal function loss. The principles of repair with the laparoscopic approach are similar to those of the open approach as the retrocaval ureteral segment needs to be repositioned to a location anterior and lateral to the cava. If the ureter encircles the cava, a dismemberment and reanastomosis approach is needed. If the ureter does not encircle the cava, a simple ureterolysis may be sufficient.

The laparoscopic approach to the retrocaval ureter was first reported by Baba et al in 1994.¹⁴ Subsequently, Salomon et al used a retroperitoneal approach to the retrocaval ureter with success.¹⁵ In the transperitoneal approach, cystoscopy with ureteral catheter placement is first performed. The patient is then placed in a right lateral position at 45°. Typically, the camera port is placed at the umbilicus, and three working ports are typically placed at the ipsilateral mid-clavicular line subcostally, at the iliac fossa, and in the ipsilateral flank.^{14,16,17} The last port at the flank may be optional depending on the patient’s anatomy.¹⁸ After pneumoperitoneum and medial mobilization of the ascending colon, ureteral identification and dissection are performed. Once mobilized, the ureter is transected just distal to the obstructive, circumcaval site, and the ureteral catheter is withdrawn distally. If stenotic, the retrocaval segment is excised. The distal ureteral stump is spatulated prior to reanastomosis to the proximal ureteral segment with interrupted 4-0 absorbable sutures. If the retrocaval ureteral segment cannot be freed easily from the cava, it can be left in situ after dividing the ureter both above and below this segment. The proximal and distal ureteral ends are brought anterior and lateral to the cava prior to reanastomosis. The ureteral catheter can be advanced past the repair site into the renal pelvis, followed by proximal advancement of a guide wire under fluoroscopic and laparoscopic guidance. After confirmation of appropriate guide wire location, the ureteral catheter is removed, and a double J stent is placed over the wire. A surgical drain is placed at the end of the procedure. Figure 24.4 illustrates some of these surgical steps.

The retroperitoneoscopic approach has also been used with success.^{15,19–21} The patient may be similarly placed in a modified flank position with a more exaggerated table-tilt. The camera port may be placed between the umbilicus and the anterior iliac spine, and two additional working ports can be placed at the mid and posterior axillary line.^{15,19} The surgical steps involved in the ureterolysis, ureteral transection, and

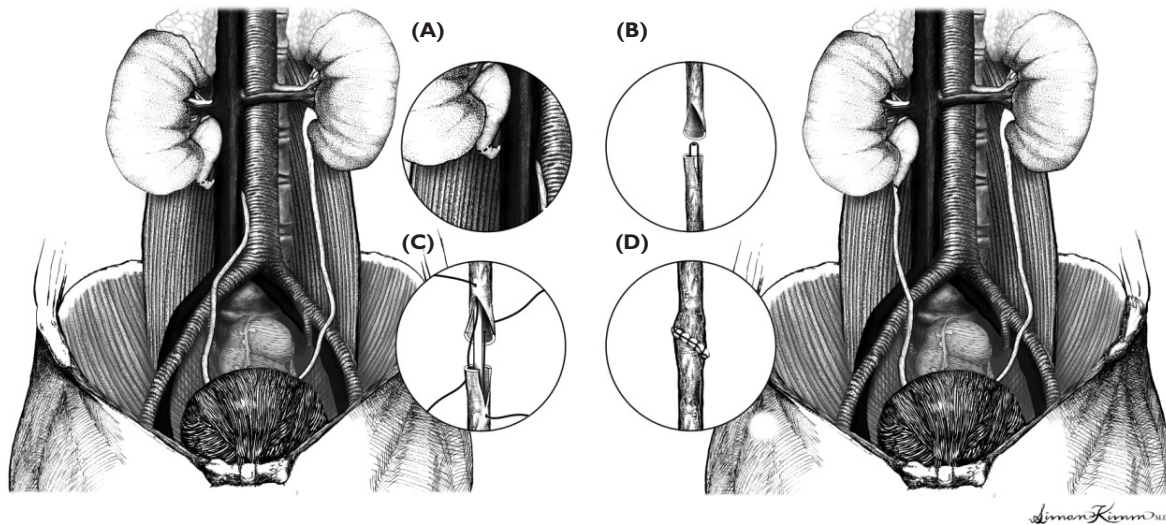


Figure 24.4 Laparoscopic ureteroureterostomy in the management of retrocaval ureter: (A) right ureteral obstruction secondary to retrocaval etiology; (B) ureteral transection, transposition, and alignment in preparation for end-to-end ureteroureterostomy; (C) ureteroureterostomy performed over an open-ended ureteral catheter; and (D) completion of ureteroureterostomy. Courtesy of Dr Simon Kimm.

reanastomosis in a more anterior lateral position are similar to those for the transperitoneal approach.

The first reported cases were quite challenging and took 7–9 hours, with the end-to-end ureteral anastomosis step being the most difficult portion of the surgery.^{14,17} With further experience in laparoscopic techniques, however, operative times have decreased in subsequent cases to approximately 4 hours.^{16,18,22} In general, patients experience minimal postoperative pain and short convalescence. The ureteral stent can be removed at 4–6 weeks, and follow-up nuclear drainage studies can be obtained to rule out recurrence of obstruction.

LAPAROSCOPIC URETEROLYSIS IN IDIOPATHIC RETROPERITONEAL FIBROSIS

Idiopathic retroperitoneal fibrosis is a chronic inflammatory process that comes to urologic attention when ureteral obstruction occurs as a result of extrinsic compression and encasement by surrounding retroperitoneal fibrotic tissues. The progressive nature of the inflammatory process can lead to renal function deterioration and obstructive symptoms such as flank pain. Radiographic findings on intravenous or retrograde pyelogram typically demonstrate medial deviation of the involved ureter and the absence of intraluminal obstructive lesion. Functional studies such as pressure-flow and diuretic nuclear renal scan typically demonstrate delayed urinary drainage. Causes

of retroperitoneal fibrosis are myriad and include inflammatory bowel disease, vascular aneurysms, radiation, malignancies, and retroperitoneal bleeding. However, most cases are idiopathic.

The laparoscopic approach to the idiopathic retroperitoneal fibrosis-associated ureter remains challenging with only a few cases described in the literature.^{23–27} The principles of the laparoscopic approach include biopsy of retroperitoneal tissue for diagnosis, complete ureterolysis with ureteral mobilization to a more lateral position, and intraperitonealization of the ureter. First reported by Kavoussi et al in 1992, laparoscopic dissection and mobilization of the entrapped ureter is feasible but can be technically challenging.²³ The extent of retroperitoneal fibrosis will determine the level of technical difficulty with long strictures requiring more operative time than shorter ones.²⁴

A transperitoneal approach is typically used following the placement of a ureteral stent. In such an approach, the patient is placed in a modified flank position. The laparoscopic camera port can be placed along the anterior axillary line 2 cm above the umbilicus. Typically three other working ports are needed on the ipsilateral side. The most cranial port is placed in the mid-clavicular line 2–3 cm below the costal margin. A second port is placed 2–3 cm lateral to the umbilicus, and a third just lateral and 2–3 cm above the anterior superior iliac spine. In cases where both ureters are affected and require surgical mobilization, additional ports are placed in the corresponding locations on the contralateral side of abdomen. When bilateral repair is to be done in the same setting, the camera port can be

placed in the midline at the umbilicus. In more difficult cases, repair of the second ureter can be performed at a different time.²⁵

Following establishing pneumoperitoneum and port placement, the colon is first mobilized and reflected medially. After a biopsy of the fibrotic tissue is taken for diagnostic purposes, ureterolysis can be initiated either near the renal hilum or below the iliac vessels, two locations where the ureter is typically not involved by the fibrotic process. Using blunt and sharp dissection techniques, the ureter is mobilized circumferentially. Use of electrocautery is minimized to avoid inadvertent injury to the ureter, major vascular structures and the periaortic nerve plexus. Use of a vessel loop around the freed portion of the ureter can provide needed traction and facilitate dissection. Once ureteral mobilization is complete, the ureter is retracted anterolaterally into the peritoneal cavity. The parietal peritoneum is reapproximated with sutures or clips to close the retroperitoneal defect, and normal intraperitoneal fatty tissue or the greater omentum can be interposed between the ureter and the retroperitoneal defect. Demirici et al reported a successful modification for right-sided ureterolysis where the right colon and cecum were placed posterior to the relocated ureter to fill the retroperitoneal defect.²⁸ It is important not to kink the ureter excessively in its lateral intraperitoneal placement. The ureteral stent or stents are left in place for 2–3 weeks, and follow-up nuclear functional studies are recommended at 3–6 months postoperatively to evaluate urinary drainage.

Although associated with longer operative times, the laparoscopic approach has been shown to be effective in minimizing perioperative morbidity and convalescence.²⁷ However, given the rarity of idiopathic retroperitoneal fibrosis, its uncertain natural history and the lack of long-term data, close patient follow-up is crucial in the postoperative setting.

LAPAROSCOPIC URETERONEOCYSTOSTOMY

Ureteral reimplantation (ureteroneocystostomy) is indicated in the setting of distal ureteral stricture disease, ureteral injury, and, rarely, non-resolving primary vesicoureteral reflux. While both refluxing and non-refluxing reimplantations have been performed laparoscopically, the former is much more common.

The first laparoscopic ureteroneocystostomy was reported by Reddy and Evans.²⁹ Since then, other investigators have reported excellent results.^{30–34} In the transperitoneal approach, a supine or low dorsal

lithotomy for patient positioning is ideal, with the table tilted at 15–45° of Trendelburg to encourage the overlying bowel out of the pelvis. The transperitoneal approach provides excellent exposure and is important in longer strictures that may require a psoas hitch for a tension-free repair. Typically, a total of four ports are needed, with the camera port placed at the umbilicus. Working ports may be placed in the midline approximately 3 cm above the symphysis pubis and between the xyphoid and umbilicus. The last working port is placed just lateral to the lateral edge of the ipsilateral rectus abdominus between the umbilicus and the anterior superior iliac spine or alternatively just lateral to McBurney's point on the right or the corresponding location on the left. The bladder is kept empty during ureteral mobilization and dissection. Following port placement and colonic mobilization, the ureter is identified and circumferentially mobilized. An umbilical tape or vessel loop can be placed around the ureter and used for traction during dissection distally towards the bladder. Care is taken to preserve periureteral blood supply with minimal use of electrocautery. The ureter is transected, and the pathologic ureteral segment is resected or ligated and left in situ. The normal ureteral end is then spatulated. The bladder is filled with saline, and a site closest to the spatulated ureter is selected for the cystostomy. In the case of a refluxing anastomosis, a 1–2 cm bladder cystostomy is made through all layers of the bladder. In a non-refluxing anastomosis, which is rarely performed in the adult population, a 2–4 cm incision over the detrusor layer is made followed by a 1 cm mucosal incision distally. A guide wire is advanced into the renal pelvis via the spatulated ureteral opening laparoscopically or cystoscopically. After fluoroscopic confirmation of the guide wire location, a ureteral stent is passed over the wire. In the refluxing reimplantation, the anastomosis is created over the stent with four to five interrupted fine absorbable sutures that traverse all layers of the bladder and the ureter, ensuring mucosa-to-mucosa apposition (Figure 24.5). In the non-refluxing reimplantation, the repair is started by the placement of a muscle holding stitch that traverses all layers of the bladder and the ureter. Additional interrupted absorbable sutures are then placed between the mucosal layers of the bladder and the ureter. The ureter is placed within the detrusor trough, and the edges of detrusor muscle are then approximated over the ureter to create a submucosal tunnel.^{34–36} The repair is then tested by bladder filling and direct laparoscopic visualization. At the conclusion of the repair, a pelvic drain is left for 1–2 days, and the ureteral stent is left for 4–6 weeks. Follow-up

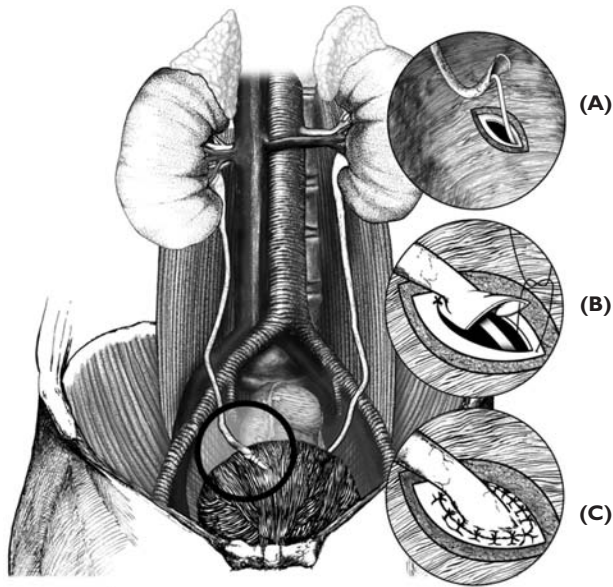


Figure 24.5 Laparoscopic ureteroneocystostomy: (A) cystotomy creation and distal ureteral spatulation; (B) ureteral reimplantation (refluxing type) over an indwelling ureteral stent; and (C) completion of ureteral reimplantation. Courtesy of Dr Simon Kimm.

imaging studies such as intravenous pyelogram or nuclear renal scan should be obtained to ensure patency. From published reports, patients can expect a minimal need for postoperative analgesics, a short convalescence, and satisfactory urologic outcomes.^{29–34}

In laparoscopic ureteroneocystostomy, it is important to avoid anastomotic tension, ureteral torsion, and angulation. When additional length is needed, the ureter can be mobilized further proximally. Alternatively, a vesicopsoas hitch can be used.^{31,32} The vesicopsoas hitch can be easily accomplished by adequately taking down the peritoneal attachments and anchoring the bladder to the ipsilateral psoas tendon using 3-0 interrupted prolene suture.³⁷ For mid-ureteral strictures or injuries, the creation of a Boari flap may be necessary to ensure a tension-free anastomosis (Figure 24.6). Fugita et al described their initial experience with laparoscopic Boari flap creation in three patients with ureteral obstruction.³⁸ In their approach, following dissection and transection above the diseased area, the ureter is then spatulated. Following bladder mobilization, the anterior diagonal bladder flap is created with a base of 4 cm and an apex of 2 cm. A J-J stent is then placed into the ureter laparoscopically using a guide wire. The spatulated ureter is then anastomosed to the flap using 4-0 absorbable sutures in an interrupted fashion. The distal end of the stent is placed within the bladder and the flap is tabularized using 2-0 absorbable sutures.

In addition to the transperitoneal laparoscopic approach to ureteral reimplantation discussed above, the intravesical approach may also be performed. Recently, Gill et al reported their experience with the intravesical approach to Cohen cross-trigonal non-refluxing ureteroneocystostomy involving three patients with symptomatic unilateral reflux.³⁹ In their approach, the patients are typically positioned in the modified lithotomy position. Following cystoscopy with stent placement in the affected ureter, two 5 mm balloon tipped trocars are placed suprapubically into the distended bladder one finger breadth superior to the pubis on either side of the midline under cystoscopic guidance. The balloons are then inflated and cinched to create a watertight seal, and the side ports of the trocars are connected to continuous suction. A 24 Fr resectoscope with a Collins knife is used to score the direction and length of the proposed cross-trigonal submucosal tunnel. Through the 5 mm ports, a laparoscopic grasping forceps and electrocautery scissors are used on either side of the scored marking to raise the bladder mucosa and create a submucosal bed for the proposed tunnel. The affected ureteral orifice is then grasped and retracted anteriorly. The Collins knife is then used to carefully dissect the ureter and intramural ureter. Dissection is performed to include 2–3 cm of extravesical ureter. A 3-0 absorbable suture is then inserted through a suprapubic port. With a laparoscopic needle driver, a deep stitch is passed through the detrusor at the apex of the trough and subsequently through the posterior lip of the mobilized ureteral orifice and tied extracorporeally. Two additional stitches are placed to secure the neoureteral orifice. The cystotomy at the site of the original ureteral hiatus is suture closed. The bladder mucosal flaps raised are reapproximated over the ureter within the submucosal trough using 4-0 absorbable suture in an interrupted fashion. Clinical experience in the intravesical approach is very limited. However, with this technique, patients appear to experience a short convalescence, decreased analgesic requirement, and good cosmesis.³⁹ Reflux resolution was noted in two patients at 6-month follow-up.

LAPAROSCOPIC TRANSURETEROURETEROSTOMY

To date, there has been no clinical case of laparoscopic transureteroarterostomy in the literature. This may be related to the fact that there are more attractive alternatives such as bladder flaps that would not affect the unaffected renal unit. In cases of palliative surgery to

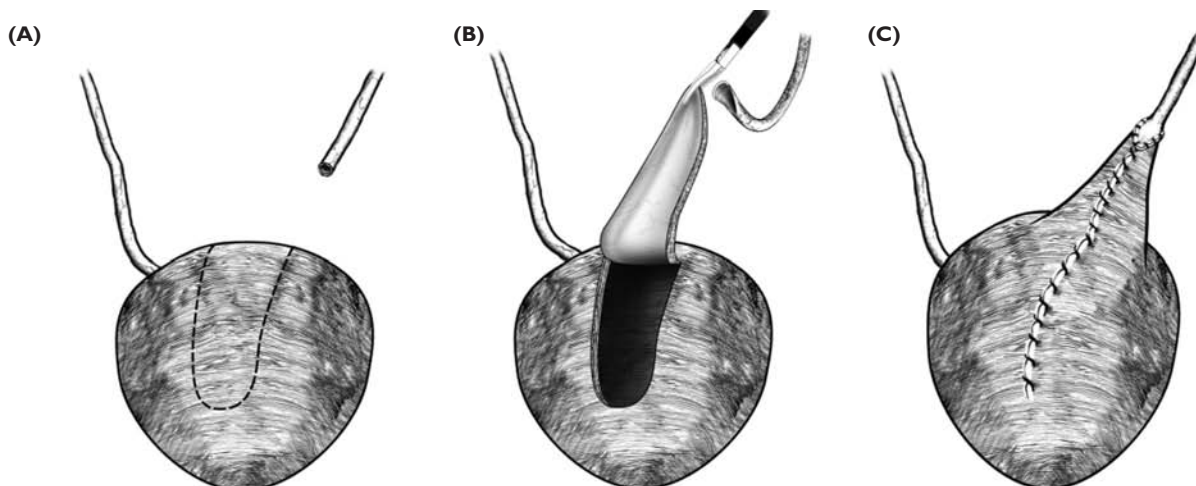


Figure 24.6 Laparoscopic Boari flap creation: (A) flap outline on bladder surface in preparation for reconstruction; (B) flap creation with spatulation of distal ureteral end; and (C) Boari flap creation involving ureteroneocystostomy and flap tubularization. Courtesy of Dr Simon Kimm.

relieve urinary obstruction, options such as percutaneous drainage are often easier. Nevertheless, Dechet et al demonstrated that laparoscopic transureteroureterostomy is technically feasible in a porcine model.⁴⁰ Operative times ranged from 2.5 to 6 hours, and eight of the nine procedures were described to be successful.

CONCLUSIONS

Laparoscopic application to the ureter has become increasingly widespread in the field of urology in recent years. Successful clinical applications of laparoscopy to pyeloplasty, pyelolithotomy, ureterolithotomy, retrocaval ureter, idiopathic retroperitoneal fibrosis, and ureteroneocystostomy have been well demonstrated. With greater surgeon experience in advanced laparoscopic suturing and reconstructive skills, the increasing importance of laparoscopy is expected to continue in ureteral surgery in the future.

ACKNOWLEDGMENT

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25 Fetal surgery for obstructive uropathy

Jason Wilson and Laurence S Baskin

INTRODUCTION

Since its inception in the early 1980s, fetal surgery has undergone many changes. Early fetal surgery for bilateral hydronephrosis was primarily undertaken to prevent pulmonary hypoplasia. Hysterostomy at that time was utilized for fetal urinary diversion if the expected time to lung maturity was greater than 2–3 weeks.¹ Evolving technology has allowed earlier diagnosis and less invasive ways of achieving fetal urinary diversion in pregnancies complicated by oligo- or anhydramnios. With the invention of more stable types of double pigtail shunts (Rocket Medical, Watford, England, Cook Urological, Indiana, USA), vesicoamniotic shunting has become more stable with fewer shunts becoming dislodged or removed. Shunting has proven useful in preserving amniotic fluid levels thereby allowing fetal pulmonary maturation, as demonstrated in outcomes with early efforts at urinary diversion.¹ Outcomes in respect to preserving or improving renal or bladder function remain

controversial. The number of shunts dislodged is still a concern and the need for replacement is common despite advances in technology. Fetal cystoscopy is an evolving technique that may prove useful in diagnosis and management of obstructive lower urinary tract pathology in the fetus. The indications are similar to those for vesicoamniotic shunting and it has been used with success in experienced centers (Figure 25.1).

Fetal surgery for myelomeningocele (MMC) was reported in 1998.² Fetal intervention for MMC has proven to be safe and effective with a considerable decrease in mortality secondary to complications of preterm delivery with the evolution of technique. In utero MMC closure has reportedly prevented the need for ventriculoperitoneal shunting in a significant number of children,³ but has not been shown to significantly improve urodynamic parameters of children with spina bifida in early life.⁴ An ongoing prospective clinical trial (Management of Myelomeningocele study), will help establish the long-term benefits of neonatal intervention.

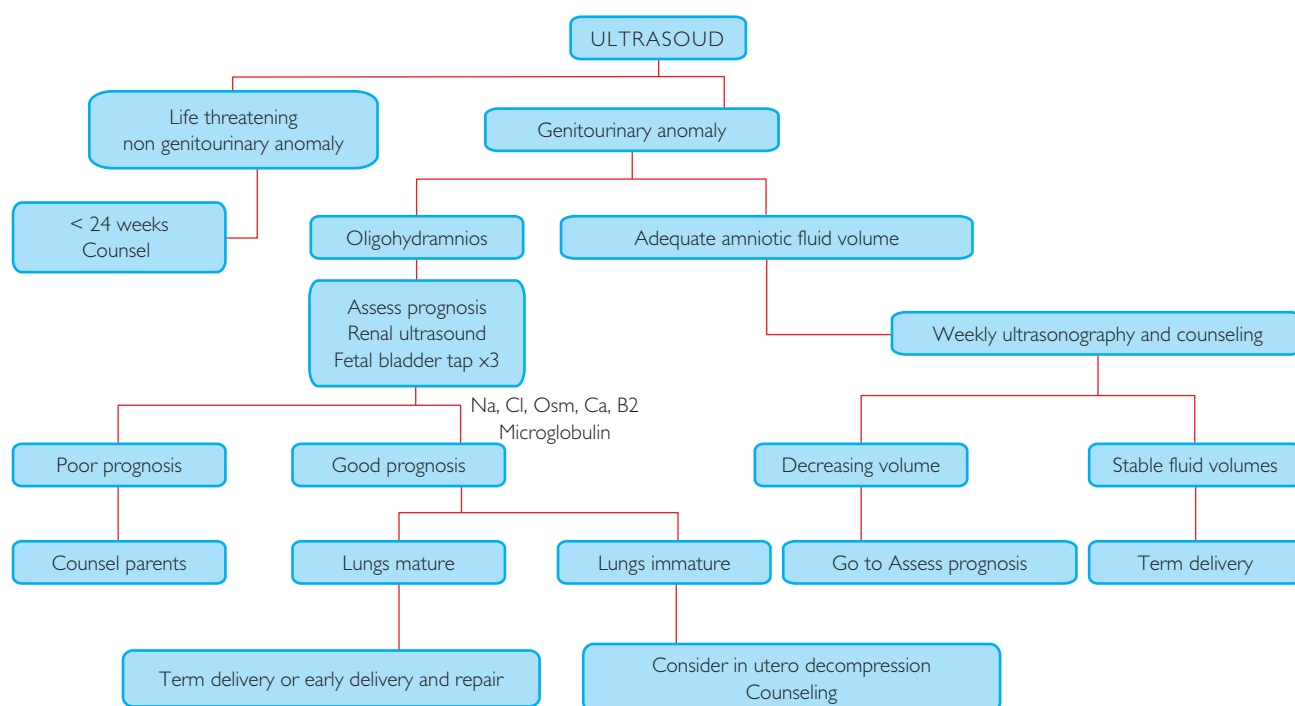


Figure 25.1 Treatment algorithm for bilateral, antenatally detected hydronephrosis.

Fetal surgery is an evolving area of medicine that still poses significant risk to both the fetus and the mother, and should be employed under specific indications with supervision and facilitation by experienced members of fetal medicine and surgical teams.

VESICOCENTESIS AND URETEROCELE DECOMPRESSION

Percutaneous, ultrasound guided aspiration of urine from the fetal bladder is used in collection of urine for analysis. It has also been described in therapy for obstructive ureterocele in rare cases where oligohydramnios is present.⁵⁻⁷

A combination of maternal and fetal anesthesia is used to achieve a safe operative procedure. Standard surgical and sterile technique are observed. Color Doppler sonography is utilized in avoiding injury to umbilical vessels. A 20 or 22 gauge needle with ultrasound guidance is used to enter the bladder of the fetus. Several 20ml syringes are used to empty the fetal bladder and secure fetal urine for chemical analysis. The ureterocele, having been demonstrated in previous and current imaging, is punctured under direct guidance until decompression is sonographically evident.⁶ Ureterocele puncture is undertaken at the site with maximal distance from the bladder wall to avoid potential injury.

Postoperative amniotic fluid index (AFI) and the appearance of fetal bladder are monitored for success of decompression. If AFI becomes abnormal or the ultrasound demonstrates recurring findings, induction of labor or repeat vesicocentesis are considered, depending upon the stage of pregnancy and the safety with which either option can be employed.

VESICOAMNIOTIC SHUNTING

Vesicoamniotic shunting should currently be considered in cases of fetal lower urinary tract obstruction with oligohydramnios in which the fetus does not have evidence of renal dysplasia. Early attempts at identifying kidneys without dysplasia were dependent upon the return of amniotic fluid to normal levels within an appropriate interval after vesicocentesis; modern efforts are supported by fetal urine analysis and improved sonographic imaging. Accepted normal parameters indicating remaining fetal renal parenchymal function include urine osmolality less than 210 mOsm/l, urine sodium less than 100 mEq/l, and urine chloride less than 90 mEq/l. Ultrasound findings

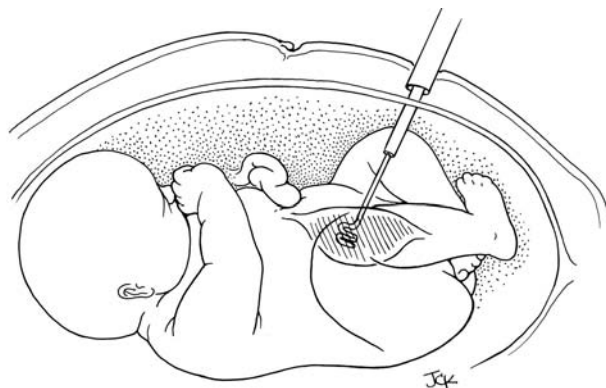


Figure 25.2 Schematic illustrating placement of vesico-amniotic shunt.

of increased parenchymal echogenicity and/or renal cysts portend a poor prognosis for renal function. Shunting and other invasive testing should be postponed until the 16th week of gestation to avoid injury to the membranes.⁸

Maternal anesthesia is induced and the procedure is initiated observing standard surgical technique. The trocar of the chosen shunt is positioned, under ultrasound guidance, superficial to the fetal bladder. A small, maternal skin incision is made to facilitate the ease with which the trocar is correctly positioned. Fetal anesthesia may be induced at this point in the procedure if needed. Using a quick and controlled motion, the fetal bladder is entered, allowing urine sampling and/or placement of the double pigtail catheter. The trocar is positioned correctly within the vesical space to allow placement of the bladder coil. The coil is seen to have been positioned correctly under ultrasound guidance and the straight portion of the catheter is advanced as the trocar is slowly removed, allowing the straight portion to assume a position in the bladder wall and fetal skin. When the trocar is visualized at the level of fetal skin, the amniotic coil and remaining catheter are passed to assume a position within the amniotic space. If the amniotic space has become obfuscated secondary to low amniotic fluid volumes, an amniocentesis is necessary to prevent improper placement of the amniotic coil in the myometrium or fetal membranes⁸ (Figure 25.2).

CYSTOSCOPY

Since first described in 1992⁹ endoscopy for fetal surgery has evolved, largely, alongside advances in the development of equipment and technique. Reported success to date in the management of fetal posterior urethral valves is encouraging.^{10,11}

With general anesthesia and ultrasound guidance, a 3 mm trocar is positioned within the fetal bladder. A rigid endoscope is then passed through the trocar and cystoscopy performed for diagnosis. Posterior urethral valves are visualized and the rigid endoscope is replaced with a 2.4 mm flexible endoscope through which a 400 μ m laser fiber has been passed. The endoscope is positioned proximally within the posterior urethra allowing identification of the proper anatomic position for valve ablation. Low energy (10 W) is then used to perform ablation with direct contact with the valves enacted. Visual confirmation of valve ablation is encouraging, but visualization of the fetal urinary stream, where previously absent, is diagnostic of successful antenatal intervention. A vesicoamniotic shunt can then be placed at the team's discretion.

Tocolysis is utilized and routine follow-up observed with fetal ultrasound 1 week after the procedure.¹⁰ Welsh et al¹¹ reported successful visualization of the urethra in ten of 13 fetal patients. As technical difficulties are further minimized with technical advances, this type of definitive treatment in which the normal bladder cycling may continue after successful treatment of obstruction, may yield improved bladder and renal function in children with posterior urethral valves.

FETAL OPERATIVE CORRECTION OF MYELOMENINGOCELE

As is the case in all prenatal interventions, the mother's safety is the primary concern. Current surgical techniques were developed methodically heeding the importance of that primary objective in addition to minimizing the likelihood of preterm labor and/or premature rupture of membranes.¹² Early MMC closure in animal models led to the hypothesis that fetal surgery may decrease the interval within which the neural tissue was actually exposed to the amniotic fluid, thereby preventing or at least ameliorating long-term neurologic sequelae commonly seen in children with MMC.¹³ This has not proven tenable in early human studies but this may be attributable to the normal changes observed in voiding patterns throughout early life. Ongoing, randomized clinical trials involving the Children's Hospital of Philadelphia, Vanderbilt and University of California at San Francisco (UCSF) will provide further clinical data. In a retrospective review of six patients at UCSF who underwent neonatal correction of MMC, all exhibited detrusor filling pressures of 35 cmH₂O or higher. This series also demonstrated non-coordinated sphincteric activity in 100%.¹⁴ Long-term follow-up with the patients from the multi-center

study will need to continue through the toilet training years and beyond in order to ascertain whether early MMC closure preserves bladder function.

The selection criteria for fetal closure include age between 19 and 26 weeks gestation, normal karyotype, absence of lethal anomalies, absence of other congenital anomalies, severe Chiari II malformation, and ventriculomegaly less than 17 mm.^{3,4} Preoperative counseling is undertaken with these criteria in mind and detailed discussion including maternal and fetal risk, and potential risk to future pregnancy is crucial. The anesthesia and surgical teams proceed with epidural catheter, tocolytic agents, neuromuscular blockade, and inhaled anesthetics. Fetal monitoring throughout the pre-, intra-, and postoperative periods is crucial. Room temperature is maintained as high as possible. The uterus is exposed through a cesarean type incision and hysterostomy is performed at a level avoiding the placenta and fetal limbs. Intraoperative ultrasound aids in making the hysterostomy in the correct location. Risk of placental separation is minimized, maintaining intrauterine volume with perfusion using Ringer's lactate and exposing only the area for closure of MMC.¹⁵ With adequate exposure achieved, the defect is closed as it is during postnatal correction. Attention to the umbilical cord prevents injury and/or compression. Postoperative sonography is easily performed across a transparent dressing¹⁴ (Figure 25.3).

CONCLUSION

Prenatal intervention began with the vision that the obstructed urinary tract could be decompressed in utero preserving and/or improving renal, bladder, and pulmonary function. Unfortunately, 30 years of clinical experience has only confirmed the ability to preserve pulmonary function. Whether antenatal intervention will ultimately improve bladder and renal function as compared with children treated after birth remains to be ascertained. In one study, 63% of living patients who had undergone antenatal treatment for posterior urethral valves had developed chronic renal failure.¹⁴ Holmes et al reported that of 14 fetuses undergoing treatment for obstructive uropathy six experienced fetal demise.¹⁴ Furthermore, the pretreatment diagnosis has proven to be inaccurate in up to 40% of patients with prune belly syndrome and urethral atresia mimicking posterior urethral valves. These findings underscore the importance of careful patient selection in considering fetal intervention for obstructive uropathy. A logical criterion would be to consider the fetal patient in whom demise would be unavoidable without intervention. As more is learned in regard to technique, indications, and

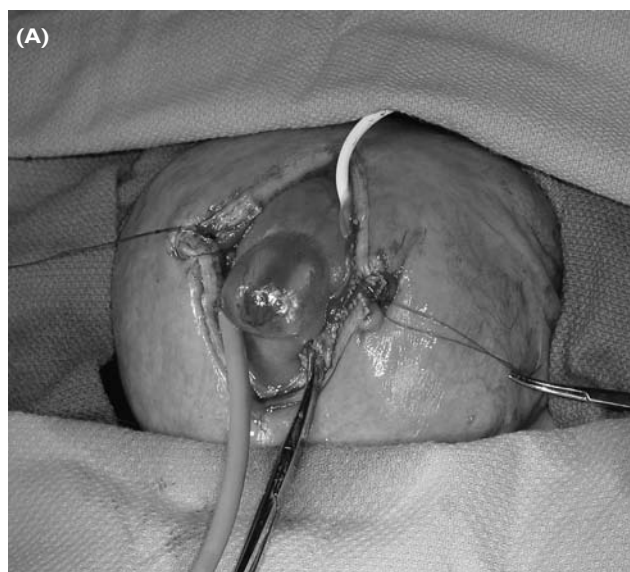


Figure 25.3 (A) In utero exposure of lumbar myelomeningocele. (B) In utero appearance after closure of myelomeningocele. Two-week postpartum appearance after in utero closure of myelomeningocele. Courtesy of Nalin Gupta MD, UCSF Neurosurgery.

accuracy of prenatal diagnosis and prevention of preterm demise and/or delivery, the range of conditions for which fetal surgery is advocated may broaden.

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26 Injectables in pediatric urology: reflux, bladder neck, and stomas

Wolfgang H Cerwinka and Andrew J Kirsch

INTRODUCTION

The concept of treating sphincteric deficiency by injection of bulking materials was first employed in 1955 by injecting paraffin wax into the perineum for the treatment of stress urinary incontinence (SUI).¹ In 1973, Berg and Politano et al independently introduced a technique for the treatment of SUI by endoscopic injection of bulking material into the bladder neck.^{2,3} In 1981, Matouschek described a cystoscopic method involving injection of bulking material to treat vesicoureteral reflux (VUR).⁴ Subsequently, O'Donnell and Puri published a series of subureteric injections in pigs and humans in 1984.⁵ Early results of endoscopic injection treatments were modest due to a lack of experience and the adverse properties of bulking materials. However, the advent of superior injectables and a growing body of clinical evidence support their use in pediatric patients. While endoscopic procedures begin to assume the role of first line treatment for VUR, SUI, and stomal incontinence, open surgical repair remains a viable treatment option for endoscopic treatment failures or complex cases. Recent evidence suggests that success rates of open ureteral reimplantation and endoscopic treatment of VUR are not significantly different. Even though open surgical repair of SUI and stomal incontinence continues to yield higher success rates, minimally invasive procedures offer significant advantages such as greater patient convenience, outpatient setting, lower morbidity (e.g. pain, scar), fewer complications, and reduced cost.

INJECTABLE MATERIALS

Various injectable bulking materials have been used and abandoned over time in search for the ideal agent, which should be non-immunogenic, non-carcinogenic, biocompatible, and biodegradable.⁶ Historic, contemporary, and investigational injectable bulking agents are listed in Table 26.1. The use of Teflon®, the first bulking material used for the treatment of VUR and SUI, was discontinued in pediatric urology in the US because of the material's propensity to migrate to distant organs and to induce the formation of granulomas;^{35–39} carcinogenesis

of Teflon has not been reported.^{36,40} Silicone also demonstrates distant migration and granuloma formation.^{40–42} Its carcinogenic potential has been controversial but is most likely unsubstantiated.^{40,43,44} Glutaraldehyde cross-linked bovine collagen demonstrates reduced absorption as compared with native collagen and can cause allergic reactions even in patients with a negative skin test.^{45–47} Several new bulking agents are currently under investigation, such as inorganic materials (zirconium, calcium hydroxylapatite) and autologous tissue. The latter is non-immunogenic, however, cell harvest and/or cell culture are time-consuming and expensive. Dextranomer/hyaluronic acid copolymer is easy to inject, is biodegradable with stable implant volume, and its relatively large particle size prevents distant migration.^{48,49} It has been used as an injectable material in pediatric urology for over 10 years and may be, at present, the first choice injectable agent due to its safety and efficacy.¹¹ Besides biologic properties and cost of bulking agents as well as surgeon's experience, the choice may ultimately depend on approval by administrative agencies, such as the European Medicines Agency (EMA) or the Food and Drug Administration (FDA).

INJECTABLES FOR VESICoureTERAL REFLUX

VUR is one of the most common genitourinary disorders in childhood affecting approximately 1% of children.⁵⁰ It is diagnosed and graded by voiding cystourethrogram. VUR can lead to pyelonephritis, renal scarring, and hypertension. Reflux nephropathy is found in 3–25% of children and 10–15% of adults with end-stage renal disease.^{51–53}

The aim of VUR treatment is to prevent pyelonephritis and to preserve renal function; however, there is disagreement regarding the optimal treatment, even among specialists.⁵⁴ Most children diagnosed with VUR receive antibiotic prophylaxis regardless of VUR grade. At some centers grade I VUR is not an indication for antibiotic prophylaxis unless the patient's condition deteriorates. Indications for surgical management of

Table 26.1 Historic, contemporary, and investigational bulking agents

Bulking material	Composition	Particle size (μm)	Biodegradable	Granuloma	Migration
Polytef (Teflon [®] , Urethrin [™] 2-4)	Polytetrafluoroethylene (PTFE)	5-100	No	Yes	Yes
Silicone (Macroplastique [®] , Bioplastique [™]) ^{7,8}	Polydimethylsiloxane (PDMS)	16-400	No	Yes	Yes
Collagen (Zyderm [®] , Zyplast [®] , Contigen [®] , GAX-35, GAX-65) ^{9,10}	Glutaraldehyde cross-linked (GAX) bovine collagen		Yes	No	No
Dextranomer/hyaluronic acid copolymer (Deflux [®]) ^{11,12}	Dextranomer/hyaluronic acid (Dx/HA) copolymer	80-250	Yes	No	No
Detachable membrane system ^{13,14}	Polydimethylsiloxane balloon filled with hydroxyethylmethacrylate or poly-N-vinyl pyrrolidinone		No	No	No
Calcium hydroxylapatite (Urocol, Coaptite [®]) ^{15,16}	Synthetic calcium hydroxylapatite	75-125	No	No	No
Zirconium (Durasphere [®]) ¹⁷	Pyrolytic carbon-coated zirconium oxide	212-500	No	No	Yes
Polyvinyl alcohol foam (Ivalon [®]) ¹⁸	Polyvinyl alcohol	150-250	No	No	No
Bioglass ^{19,20}	Silicone oxide, calcium oxide, calcium silicate, sodium oxide	120-355	No	No	No
Radiopaque polymeric microspheres ²¹	Methyl methacrylate triiodobenzoyloxyethylmethacrylate copolymer	45-81	No	No	No
PCL microparticle-dispersed PLGA solution ²²	PCL and PLGA	100-200	Yes	No	
PLGA microspheres ²³	PLGA	40-70	Yes	No	No
Polyacrylonitrile hydrogel (Hypan [®]) ²⁴	Polyacrylonitrile/acrylamide copolymer				
Autologous chondrocytes/alginate copolymer ^{25,26}	Autologous cultured chondrocytes				
Autologous fat ^{27,28}	Harvested autologous adipous tissue				
Autologous collagen ²⁹	Harvested autologous collagen				
Fetal bladder tissue ³⁰	Cultured heterologous fetal bladder tissue				
Small intestinal submucosa ^{31,32}	Liquified small intestinal submucosa				
Myoblasts and fibroblasts ³³	Cultured autologous myoblasts and fibroblasts				
Myoblasts ³⁴	Cultured myoblasts				

PCL, polycaprolactone; PLGA, polylactideglycolic acid.

VUR are failure of antibiotic prophylaxis and/or persistence of VUR. Options for surgical correction of VUR are open/laparoscopic ureteral reimplantation or endoscopic treatment. Ureteral reimplantation has a success rate of 95–99% for grade I–IV and 80% for grade V VUR.^{55–57} For surgical techniques of ureteral reimplantation refer to Chapter 28.

After endoscopic treatment for VUR was introduced in 1981, overall success rates were shown to be dependent on the type of bulking agent used as well as patient selection, surgeon's experience, and technique.^{4,58,59} Endoscopic injection is the treatment of choice for VUR grade I–IV. For success rates of endoscopic treatment refer to Table 26.2. Interpretation of results is biased by definition of success (e.g. number of treatments to achieve cure, defining cure as grade 0 or I VUR, patient versus ureteral cure), follow-up time, and patient drop-out rate, but success now ranges from 93 to 96% for grade I–IV VUR.^{62,65,66} Endoscopic procedures not only approach success rates of open surgical repair but offer significant advantages such as greater patient convenience, outpatient setting, lower morbidity (e.g. pain, scar), fewer complications, and reduced cost.^{69,70} The type of surgical treatment depends ultimately on an interactive decision making process involving parents and pediatric urologist with a parental preference for endoscopic treatment.^{71,72} Not surprisingly the number of endoscopic injections has increased in the US.⁷³

The principal concept underlying endoscopic management of VUR involves the injection of a bulking agent to coapt the ureteral orifice and detrusor tunnel (Figure 26.1). The formed bulge thereby elongates the submucosal ureter, creates a point of fixation, and coapts the ureteral wall.^{5,11} The technique was introduced as 'sub-ureteric Teflon injection' (STING).⁷⁴ The modified STING procedure, known as the hydrodistention implantation technique (HIT) is rapidly becoming the technique of choice worldwide, achieving success rates of over 90% after a single treatment.⁵⁹

Cystoscopy is performed with a pediatric cystoscope with an off-set lens. An off-set lens permits direct passage of the needle in line with the ureter without bending the needle. The bladder is filled to less than half volume to permit visualization of the ureter and avoid tension within the submucosal layer of the ureter secondary to overdistention; the needle is inserted within the ureteral orifice to the mid-ureteral tunnel at the 6 o'clock position. Sufficient bulking agent is injected to produce a bulge, which initially coapts the detrusor tunnel, while a second implant within the most distal intramural tunnel leads to coaptation of the ureteral orifice (approximately 1–1.5 ml). If the two intra-ureteric submucosal injections (double HIT method) fail

to coapt the ureter, a classic STING injection is conducted. Rarely, a supraureteric injection is needed to achieve adequate coaptation (Figure 26.2).

Antibiotic prophylaxis is continued until resolution of VUR has been confirmed, usually 2 weeks to 3 months postoperatively. If VUR persists, a second endoscopic treatment is performed with a 90% success rate.⁷⁵ Failure of repeated injection in select patients (e.g. young children with grade II or higher VUR and propensity for pyelonephritis) may be an indication for ureteral reimplantation. Prior injection treatment does not cause any difficulties if ureteral reimplantation is subsequently required.^{76,77} Endoscopic treatment as an initial step in the management of complicated VUR (e.g. status after open surgery, duplicated ureter, bladder dysfunction) is acceptable because of a 68% success rate after first injection and avoidance of potentially complex open surgery.⁷⁸ After initial concern that associated voiding dysfunction may be a negative predictor for success of endoscopic treatment, more recent studies have shown similar cure rates in patients with or without voiding dysfunction.^{78–80} In 25% of our cases, daytime urinary incontinence and urgency improved after successful endoscopic treatment (Kirsch, unpublished data). Endoscopic treatment of VUR in duplicated ureters yields success rates ranging from 63 to 73%.^{78,81} Injection of bulking agents was shown to be an excellent choice after failed ureteral reimplantation with cure rates from 80 to 95% after one or multiple injections.^{78,82,83}

The most significant potential complication of endoscopic treatment for VUR includes a less than 1% risk of ureteral obstruction.^{58,84} Febrile urinary tract infections have been seen in 8%, and de novo contralateral VUR, although not a direct complication of treatment, has been reported to be approximately 15%.^{76,85}

INJECTABLES FOR URINARY INCONTINENCE

SUI in childhood is caused by decreased bladder outlet resistance secondary to anatomic (e.g. bladder exstrophy–epispadias complex) and/or functional (e.g. neurogenic bladder) factors. In comparison to adults, childhood SUI is rare but has significant impact on self-esteem and quality of life. Preservation of renal function is of highest priority; therefore, when dealing with an insufficient bladder outlet, bladder function also needs to be assessed to determine the presence of detrusor overactivity and/or low bladder compliance.⁸⁶

Treatment to correct deficient bladder outlet resistance in childhood usually involves surgery. For surgical techniques of open reconstruction refer to Chapter 33.

Table 26.2 Success rates of endoscopic treatment for vesicoureteral reflux (VUR). Meta-analysis by Elder et al.⁶⁰ summarizes the results up to 2003. More recent series are shown in this table

Reference	Bulking agent	Injected volume (ml)	Ureters	Follow-up	Success by VUR grade (%)					Success (%)	
					I	II	III	IV	V	Initial	Final
Elder et al, 2006 ⁶⁰	Various	0.2–1.7	8101	variable	79	79	69	58	63	76	85
Capozza et al, 2004 ⁶¹	Various	0.2–2.2	1694	12–204 months		88	75	52			77
Kirsch et al, 2004 ⁵⁹	Dx/HA	0.5–1.5	119	3–12 months	100	92	91	90		92	
Kirsch et al, 2006 ⁶²	Dx/HA	0.8–2.0	139	3–18 months	100	93	92	96		93	
Van Capelle et al, 2004 ⁶³	PDMS	0.2–2	311	3–110 months		80	73	73			75
Kajbafzadeh et al, 2006 ⁶⁴	Ca hydroxylapatite	0.4–0.6	364	6 months	89	76	69	58	63		69
Yu and Roth 2006 ⁶⁵	Dx/HA	1	162	2–26 months	89	95	85	68		87	93
Puri et al, 2006 ⁶⁶	Dx/HA	0.2–1.5	1101	3–46 months	100	93	78	76		87	96
Lorenzo et al, 2006 ⁶⁷	PDMS		351	72 months	71	79	72	63	40		72
Pinto et al, 2006 ⁶⁸	Dx/HA		86	3 months	92	89	60	57			84

Initial success, after one treatment; final success, after two or more treatment; Dx/HA, dextranomer/hyaluronic acid; PDMS, polydimethylsiloxane.

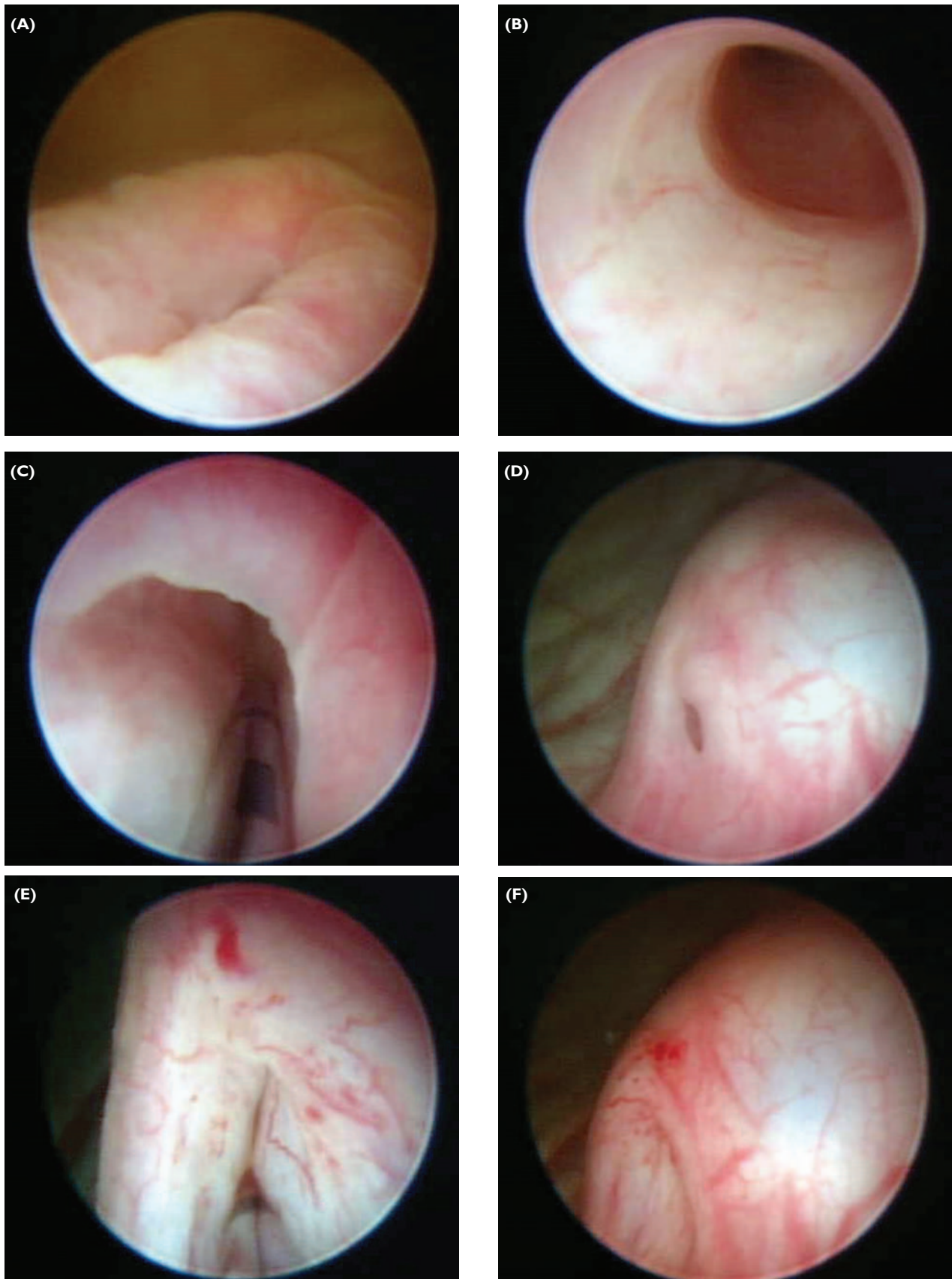


Figure 26.1 Endoscopic treatment of vesicoureteral reflux (VUR) (double HIT technique). Patient with grade IV VUR. (A) Left ureteral orifice. (B) Hydrodistention of left distal ureter. (C) Proximal intraureteric injection. (D) Coapted intramural ureter. (E) Distal intraureteric injection. (F) Coapted ureteral orifice.

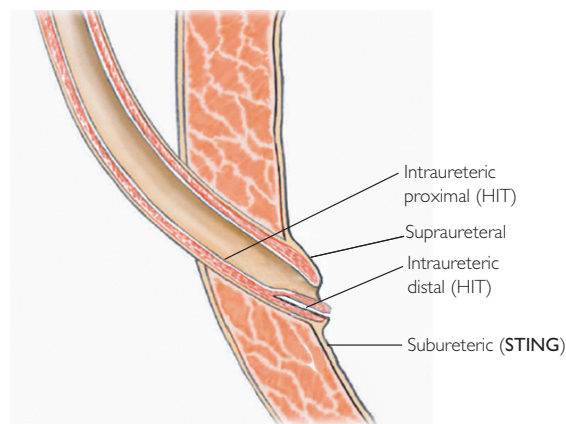


Figure 26.2 Needle placement for the endoscopic treatment of vesicoureteral reflux (VUR). The *proximal HIT* (site 1) should lead to coaptation of the proximal ureteric tunnel, proximal to distal. The *distal HIT* (site 2) is performed by placing the needle to the same depth just within the ureteral orifice and injecting slowly (while pulling the needle more superficially) until the ureteral orifice is coapted and elevated to the height of the ureteral tunnel (treated with the proximal HIT). The *double HIT* (sites 1 and 2) result is a *mountain-range* appearance of the tunnel and orifice. If the ureteral orifice does not completely coapt with intraureteric injection, alternative injection sites may be used. In this case, a classic *subureteric implantation* (STING) (site 3) is conducted. A *supraureteral injection* (site 4) may be needed as a last resort at mucosal coaptation, but is rarely used in primary cases.

Continence rates with insertion of an artificial urinary sphincter (AUS) are reported to range from 80 to 97%, for fascial slings to be 50%, and for bladder neck reconstruction up to 80%.^{87–89} Open surgery can be associated with loss of the bladder neck pop-off valve, which protects against high intravesical pressure; bladder neck reconstruction can render catheterization difficult. AUS is prone to potential mechanical failure, erosion may occur in 5–15% of all patients, infection in less than 5%.^{90,91}

In 1973, Berg and Politano et al independently published a novel technique of endoscopic treatment of SUI in adults.^{2,3} The first experience with endoscopic treatment of SUI in children was published 12 years later.⁹² Treatment success depends on patient selection, surgeon's experience, and technique. Success rates range from 20 to 78% irrespective of the bulking agents used (Table 26.3).⁹³ While open surgical repair yields higher success rates, injection treatments offer considerable advantages inherent to endoscopic procedures;¹⁰⁷ it was shown that endoscopic treatment of SUI can also improve bladder capacity.¹² Overall success rates of endoscopic treatment of SUI tend to decrease over time ranging from 40 to 50% at a follow-up of longer than 1 year.^{99,103}

Endoscopic treatment of SUI is accomplished by either a retrograde or antegrade approach (Figure 26.3).¹⁰⁸ With

a retrograde technique the bladder neck is approached distally. With the child under general anesthesia and in the lithotomy position, the bladder is irrigated with antibiotic solution. A pediatric cystoscope with an off-set lens is advanced through the urethra to the proximal bladder neck. The needle is placed submucosally and a bleb is raised in all quadrants under direct vision. If a bleb is not seen promptly, the needle is slowly withdrawn under pressure until submucosal accumulation is seen. Clean intermittent catheterization is resumed after completion of the procedure. The antegrade technique was initially described for the treatment of postprostatectomy incontinence.¹⁰⁹ The antegrade approach may provide better results for the following reasons: (1) it allows better working angles and direct injection at the funnel-shaped bladder neck; (2) the cystoscope is better stabilized than within the short female urethra; (3) it reaches maximal tissue coaptation; and (4) it permits placement of a suprapubic catheter following the procedure with avoidance of postprocedural remodeling by a urethral catheter.¹⁰⁶ Access is gained through either a Mitrofanoff channel or percutaneously with a cystoscope or laparoscope.^{102,110,111} We prefer to perform bladder neck/urethral bulking via an antegrade or combined antegrade/retrograde approach. After initial retrograde cystoscopy, the patient is placed in Trendelenburg position to minimize the risk of bowel injury. An 11 Fr peel-away access sheath (e.g. Mini-PERC™ Entry Set – Docimo Set, Cook Medical) is placed under cystoscopic guidance. When indicated, pretreatment leak point pressures may be measured using a manometer. Antegrade cystoscopy is performed by directing the cystoscope to the junction of the bladder neck and urethra. Quadrant injections with bulking material are placed. If necessary, additional injection is performed in a retrograde fashion. When indicated, leak point pressure measurements are made post-treatment. Following the injection of an adequate amount of bulking agent (usually over 3.5 ml), an 8 or 10 Fr suprapubic catheter is placed and remains for 1–2 weeks, after which clean intermittent catheterization is resumed. In patients with a history of bladder exstrophy, a more cranial percutaneous approach is taken to permit favorable working angles in light of the typically anterior bladder neck location. Care must be exercised to avoid bowel injury in this situation.

INJECTABLES FOR STOMAL INCONTINENCE

The use of intestinal segments (e.g. appendix, ileum) to create a catheterizable channel to the bladder has improved the quality of life and life expectancy for

Table 26.3 Success rates of endoscopic treatment for stress urinary incontinence

Reference	Bulking agent	Injected volume (ml)	Patients (n)	Indication	Follow-up (months)	Improved	Continent	Success rate (%)
Vorstman et al, 1985 ⁹²	PTFE	5.2–21	11	Neurogenic (N = 4) Anatomic (N = 7)	6–192	3	5	73
Wan et al, 1992 ¹⁰	GAX collagen	2.5–20	9	Neurogenic (N = 6) Anatomic (N = 3)	6–33	2	5	78
Ben-Chaim et al, 1995 ⁹⁴	GAX collagen	0.6–12	19	Anatomic (N = 19)	9–84	10	0	53
Perez et al, 1996 ⁹⁵	GAX collagen	2.5–17.5	32	Neurogenic (N = 25) Anatomic (N = 7)	3–19	8	8	50
Leonard et al, 1996 ⁹⁶	GAX collagen	2.4–13	18	Neurogenic (N = 10) Anatomic (N = 8)	5–21	4	5	50
Chernoff et al, 1997 ⁹⁷	GAX collagen	max 15	11	Neurogenic (N = 8) Anatomic (N = 3)	4–20	2	4	55
Silveri et al, 1998 ⁹⁸	GAX collagen	2–5	23	Neurogenic (N = 23)	6–54	13	0	57
Duffy et al, 1998 ⁹⁸	PDMS	mean 1.4	12	Anatomic (N = 12)	3–22	6	3	75
Kassouf et al, 2001 ⁹³	GAX collagen	2–13	20	Neurogenic (N = 20)	12–72	3	1	20
Caione et al, 2002 ⁹⁹	Dx/HA	1.8–4	16	Anatomic (N = 13) Neurogenic (N = 3)	12–24	9	3	75
Block et al, 2003 ¹⁰⁰	GAX collagen	3.4–17.5	25	Neurogenic (N = 25)	20–84	11	1	48
Halachmi et al, 2004 ¹⁰¹	PDMS	1–5	28	Neurogenic (N = 10) Anatomic (N = 18)	3–42	12	0	43
Misseri et al, 2005 ¹⁰²	Dx/HA	0.8–4.4	16	Neurogenic (N = 12) Anatomic (N = 4)	3–24	5	3	50
Lottmann et al, 2006 ¹⁰³	Dx/HA	1.6–12	61	Neurogenic (N = 27) Anatomic (N = 34)	1–84	8 of 31 at 36 months	8 of 31 at 36 months	50 at 36 months
Burki et al, 2006 ¹⁰⁴	PDMS	2.5–7.5	52	Anatomic (N = 52)	6–108	17	9	50
Guys et al, 2006 ¹⁰⁵	PDMS	0.3–10	49	Neurogenic (N = 49)	72 mean	7	16	47
Dean et al, 2007 ¹⁰⁶	Dx/HA	3–6	31	Neurogenic (N = 25) Anatomic (N = 6)	12–32	7	22	70

PTFE, polytetrafluoroethylene; GAX, glutaraldehyde cross-linked; PDMS, polydimethylsiloxane; Dx/HA, dextranomer/hyaluronic acid.

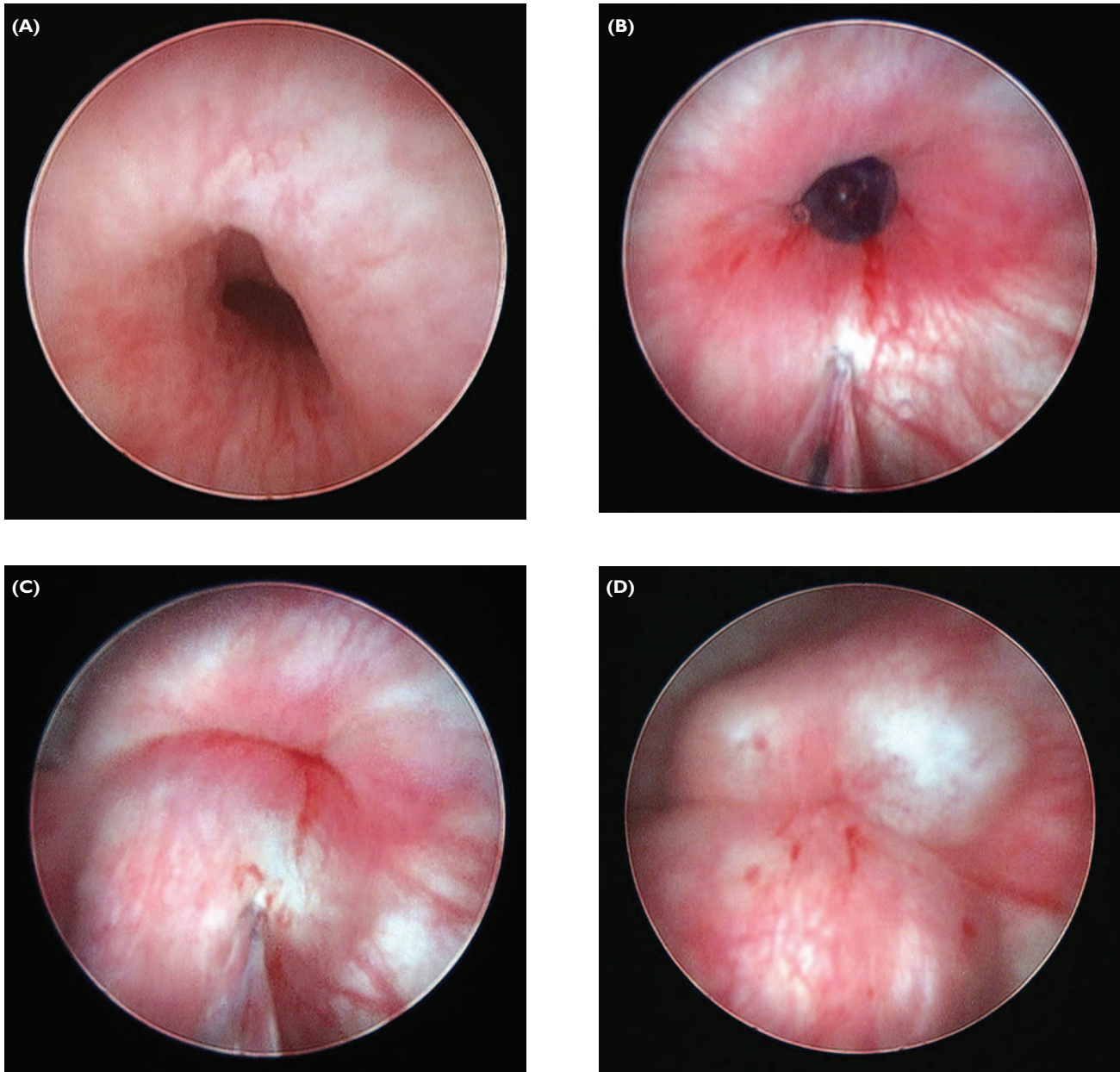


Figure 26.3 Endoscopic treatment of urinary incontinence (antegrade approach). Patient with spina bifida. (A) Open bladder neck. (B) Positioning of needle. (C) Injection of bulking agent. (D) Coapted bladder neck.

children with neurogenic bladder and other bladder abnormalities. Incontinence of such stomas may occur in 2–50% of cases mainly due to inadequate length of the flap valve or increased reservoir pressure.^{112–114} Children with intractable constipation or diarrhea may choose to undergo an antegrade continence enema (ACE) procedure for palliative treatment of neurogenic bowel symptoms.¹¹⁵ Of ACE stomas 0–23% will eventually leak.^{116–118}

Surgical options in such cases of stomal incontinence include surgical revision or placement of an AUS. Endoscopic injection of bulking agents provides an appealing alternative because many patients have

already undergone multiple surgeries and potentially complicated surgery can be avoided. Nevertheless, experience with endoscopic treatment for incontinent stomas is limited. The overall success rate with endoscopic treatment of incontinent urinary or intestinal channels ranges from 67 to 89%;^{119,120} bulking materials used and success rates of treatment are summarized in Table 26.4.

Preoperatively, all patients should undergo urodynamic testing to rule out small volume, low compliance, or bladder contractions. Under either general anesthesia or sedation the conduit is inspected with an endoscope (Figure 26.4). Bulking agent is injected

Table 26.4 Success rates of endoscopic treatment for stomal incontinence

Reference	Bulking agent	Injected volume (ml)	Patients (n)	Stoma	Intestine	Follow-up (months)	Improved	Continent	Success rate (%)
Guys et al, 2002 ¹²⁰	PDMS	3–8	6	Catheterizable channel	Appendix (N = 4) Ileum (N = 2)	8–18		4	67
Halachmi et al, 2004 ¹⁰¹	PDMS	1.3–2.6	5	Catheterizable channel	Appendix (N = 2) Ileum (N = 3)	3–13	1	3	80
Prieto et al, 2006 ¹²²	Dx/HA	2–6	14	Catheterizable channel	Appendix (N = 12) Ileum (N = 2)	3–36		11	79
Koivusalo et al, 2006 ¹²¹	Dx/HA	0.5–1	9	Antegrade Continence Enema (ACE)	Appendix (N = 4) Ileum (N = 3) Colon (N = 2)	3–53	8		89

PDMS, polydimethylsiloxane; Dx/HA, dextranomer/hyaluronic acid.

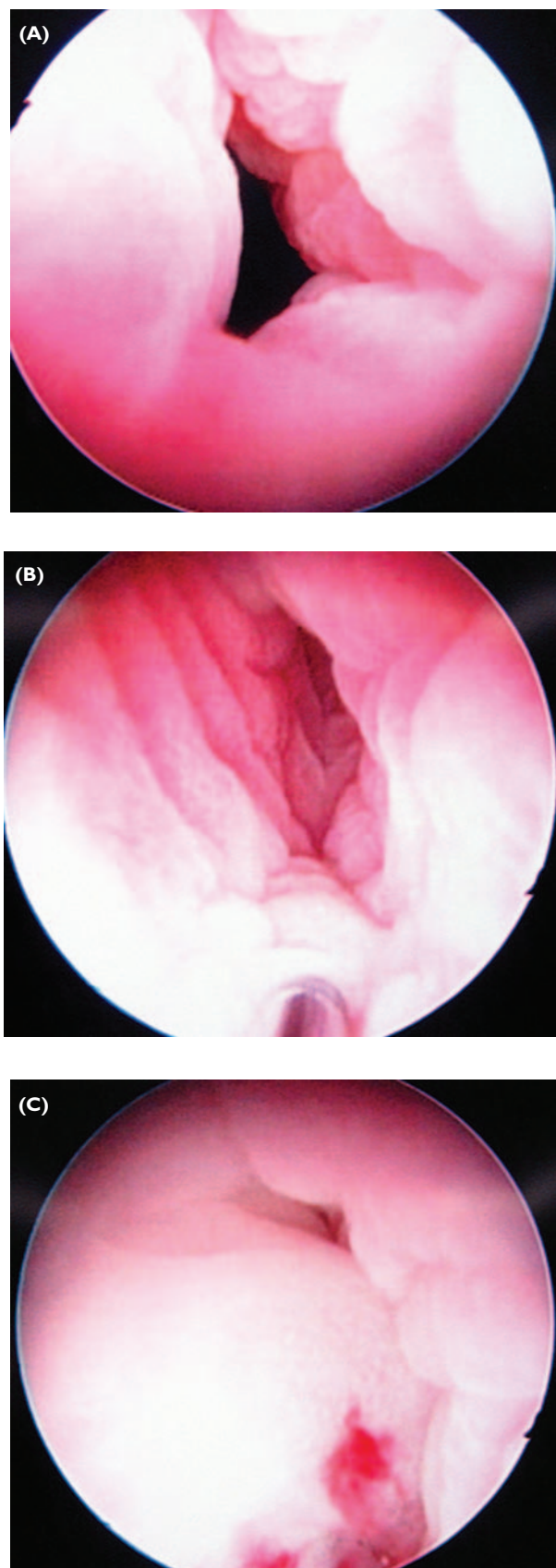


Figure 26.4 Endoscopic treatment of stomal incontinence. Patient with leaking appendicovesicostomy. (A) Open vesicoappendiceal junction. (B) Positioning of needle. (C) Coapted vesicoappendiceal junction.

submucosally into the vesico/colo-conduit junction and along the length of the conduit from the bladder/colon to the stoma to achieve occlusion of the channel lumen. In our experience it is easier to approach the bladder/catheterizable channel via the stoma and inject from proximal to distal (stoma); injection of a short segment is inadequate. It is also more difficult to place implant material into the thin-walled small intestinal lumen of a Yang-Monti tube than the appendiceal Mitrofanoff channel. There is disagreement regarding the resumption of catheterization. Some have recommended immediate intermittent catheterization while others have suggested daily catheterizations of only the stoma to prevent stomal stenosis in combination with a 10–14-day indwelling catheter to avoid traumatic catheterization.^{119,121}

CONCLUSIONS

Endoscopic procedures for the treatment of VUR, SUI, and stomal incontinence offer significant advantages to patients while avoiding potentially complicated open surgery. Success rates of endoscopic VUR treatment approach that of open surgery. Endoscopic management for SUI and stomal incontinence is improving. The development of new bulking agents in conjunction with the improvement of endoscopic techniques will continue to strengthen the role of endoscopic treatment for VUR, SUI, and stomal incontinence.

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27 Surgical management of primary vesicoureteral reflux and megaureters

William Robert DeFoor Jr and Curtis A Sheldon

VESICoureTERAL REFLUX

Introduction

Epidemiology and pathophysiology

Primary vesicoureteral reflux (VUR) is the abnormal retrograde flow of urine from the bladder towards the kidney and is one of the most common urologic abnormalities in children.^{1–3} The incidence is difficult to determine, but it has been estimated to be present in approximately 1% of children and as many as 30–50% of siblings of children with VUR.⁴ This congenital condition results from an anatomic immaturity of the ureterovesical junction resulting in an insufficiently long tunnel for the ureter as it inserts into the wall of the bladder. The incompetence of this valve mechanism thus provides a pathway for bacteria to ascend from the bladder to the kidney. VUR is a risk factor for the development of urinary tract infections (UTIs), and its association with renal scarring is well recognized.⁴ Historically, VUR was a common etiology for end-stage renal disease (ESRD) in children undergoing renal transplantation; however, more contemporary series show that ESRD results from VUR in less than 5% of cases.⁵ It is unclear if this decrease is due to misclassification in earlier studies or from the more aggressive approach to the diagnosis and treatment of UTI and VUR in the modern era.

Presentation and evaluation

VUR is most commonly diagnosed after an evaluation for recurrent febrile UTIs. VUR may also be diagnosed in asymptomatic children after an evaluation for prenatal hydronephrosis or a multicystic dysplastic kidney. Guidelines for initiating a radiographic evaluation after a UTI are controversial and may vary between regions and countries.⁶ In our institution, girls under the age of 3 and boys of any age are recommended to undergo imaging after the first febrile UTI. Girls over the age of 3 are generally evaluated only if they have recurrent UTIs.⁷

Upper tract imaging most commonly begins with renal and bladder ultrasonography (RUS). This modality is non-invasive and avoids ionizing radiation and contrast. It is helpful in assessing the kidneys for position,

size, and symmetry. Moreover, RUS is sensitive for detecting hydronephrosis and can screen for renal scarring. Intravenous pyelography is rarely, if ever, indicated in children with VUR and is less sensitive for detecting nephropathy than other imaging modalities.⁸ Renal cortical scintigraphy with dimercaptosuccinic acid (DMSA) is sensitive for detecting acute inflammation as well as chronic renal scarring and can also provide split differential function.⁹

The lower urinary tract is evaluated with either a fluoroscopic voiding cystourethrogram (VCUG) or a radionuclide cystogram (RNC). VCUG gives more anatomic detail and can document associated anomalies such as ureteroceles and paraureteric diverticula. It also allows for a more precise estimate of grading. Figure 27.1 shows a VCUG with bilateral duplication anomalies with a partial triplication on the right. An RNC may have less radiation exposure and is helpful for following patients being managed non-operatively. VUR is graded on a scale of one to five based on the International Reflux Study group guidelines. Figure 27.2 describes the currently accepted grading system.¹⁰ The prognosis is then based on the grade and laterality of the reflux. There is a strong inverse relationship between the grade of the reflux and the likelihood of spontaneous resolution.^{11,12} High grades of VUR (IV and V) resolve infrequently, but resolution has been described, particularly in male infants (Figure 27.3).¹³ Figure 27.3 shows right grade V VUR with intrarenal reflux in an infant girl who presented with sepsis.

Medical management

Initial medical management typically includes low-dose antimicrobial chemoprophylaxis to maintain urine sterility and prevent recurrent UTIs and renal injury. The ultimate goal of therapy is to preserve renal function while preventing hypertension and ESRD. The premise of initial medical management is based on the assumption that lower grades of reflux may spontaneously resolve with age and somatic growth.⁴ No guidelines are currently available that specify a subsequent follow-up regimen for children being followed non-operatively, but generally a VCUG is performed every 12–18 months.

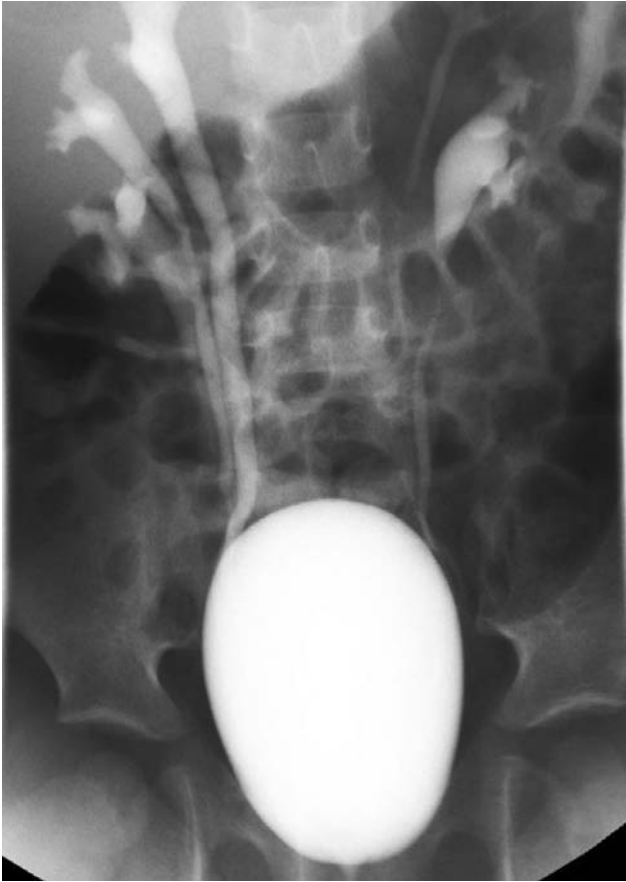


Figure 27.1 Fluoroscopic voiding cystourethrogram showing bilateral vesicoureteral reflux into duplication anomalies (partial triplication on right).

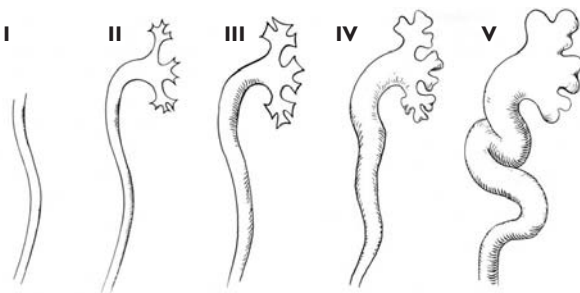


Figure 27.2 International Reflux Study classification system for grading vesicoureteral reflux. The severity of the reflux is graded from I to V. Reprinted with permission from Ginsburgs, Boris, Elsevier. All rights reserved.

Once a diagnosis is made, initial treatment with antibiotic prophylaxis is begun, typically with trimethoprim-sulfamethoxazole or nitrofurantoin. These medications are generally well tolerated; however, adverse effects of sulfonamides can cause discontinuation of the medication in up to 15% of children, most commonly due to allergic skin reactions.¹⁴ Reports of neutropenia



Figure 27.3 Fluoroscopic voiding cystourethrogram showing right grade V vesicoureteral reflux.

and thrombocytopenia with full-dose sulfonamides range from 12 to 34%.¹⁵ Other side-effects can include nausea, vomiting, abdominal pain, and hepatotoxicity. Additional concerns with long-term antibiotic usage include the development of bacterial resistance. Recent studies have brought into question whether antibiotic suppression prevents long-term adverse outcomes in VUR.¹⁶

Surgical indications

The only absolute indication for surgical intervention in VUR is progressive renal injury. This is usually manifested by breakthrough episodes of pyelonephritis despite antibiotic suppression. New cortical thinning or poor renal growth on follow-up imaging may also suggest the VUR is more clinically significant and requires antireflux surgery. Non-compliance or intolerance with antibiotic suppression is another indication for surgery. Persistent VUR in an asymptomatic patient with normal upper tracts is a relative indication and may be offered to the parents after a thorough discussion of the risks and benefits of both surgery and continued medical management. The theoretical risks of pregnancy-related complications in females with unresolved VUR should be discussed with the family and documented clearly in the medical record. Often a clinical dilemma is an asymptomatic school-age child who has had no infections since the

initial UTI that led to diagnosis, but has persistent low-grade reflux and normal upper tracts. There is some literature to support observation in these patients without continuous antibiotic suppression.^{17,18} This course of action should be undertaken with some caution again after a thorough discussion with the parents of the potential morbidity from unresolved VUR.

Once the decision has been made by the surgeon and the parents to address the reflux surgically, a full discussion of the various options should be offered to the parents. This should be clearly documented in the medical record along with a discussion of the risks and potential complications. Treatment is individualized but, in general, higher grades of reflux, particularly with significant nephropathy, are often best treated with open ureteral reimplantation. Lower grades of reflux in patients with normal upper urinary tracts are amenable to endoscopic treatment. Laparoscopic ureteral reimplantation has not gained wide acceptance due to the long operative times and steep learning curve.

Surgical intervention

Endoscopic injection

The technique for endoscopic injection of a subureteral bulking agent for the treatment of VUR (STING procedure) has been well described and utilized extensively in Europe.^{19,20} Initial studies utilized polytetrafluoroethylene (Teflon®, DuPont Corporation, Wilmington, DE) with good results;²¹ however, the agent was not approved in the US over concerns regarding the distant migration of the particles.²² In 2001, dextranomer/hyaluronic acid copolymer (Dx/HA) was approved by the US Food and Drug Administration for use in children with grades II–IV reflux. Clinical trials in Europe have reported long-term follow-up with low morbidity.²³ More recent trials have shown improvement in the success rates after one procedure, with cure rates approaching those seen with open surgery.²⁴ This has resulted in a new paradigm in the management of children with VUR, particularly those with asymptomatic lower grades of VUR. With a minimally invasive option, children who may have been treated with antibiotic suppression for years are now being offered surgical correction.^{25,26} The technical details of the endoscopic management of VUR are discussed in Chapter 26.

Open ureteral reimplantation

Ureteral reimplantation has been the gold standard for the surgical management of VUR for decades. Success rates from numerous series have been reported to be

between 95 and 99% for the abolishment of reflux with low complication rates.⁴ Prospective randomized trials between surgical and medical management show few differences in the rates of UTI and renal scarring between the two groups; however, the rate of pyelonephritis was seen to be lower in the surgical arm.²⁷ In the current age of endoscopic options available for VUR, open ureteral reimplantation is generally offered to patients with higher grades of reflux who have had problems with recurrent UTI and/or have nephropathy. The surgery is generally well tolerated with low morbidity and a short inpatient hospitalization of 1–2 days. Postoperative management is also simplified in that generally a VCUG can be deferred unless the patient has a UTI associated with fever or flank pain.

Multiple procedures have been described in the literature for ureteral reimplantation, most with similar efficacy and outcomes. The pioneering work of surgeons such as Leadbetter, Politano, Paquin, Cohen and others established principles for successful outcomes for reimplantation.^{28–30} These included adequate ureteral exposure and mobilization, meticulous preservation of blood supply, and creation of a valvular mechanism the submucosal tunnel length to ureteral diameter ratio of which should exceed 4 : 1. The early techniques and more recent variations all employ a midline cystotomy and mobilization of the ureter from within the bladder. Once adequate tunnel length is obtained, a sutured ureterovesical anastomosis is performed. The Cohen cross-trigonal technique has been well described and is probably the most commonly used intravesical reimplantation procedure in North America and Europe.^{31,32}

The extravesical approach to reimplantation without dismemberment was described by Lich and Gregoire and modified by Hodson to incorporate ureteral advancement.^{33,34} Zaontz coined the term ‘detrusorrhaphy’ to anatomically describe this procedure and reported excellent initial results.³⁵ This has become widely used in North America, particularly for unilateral cases. In our institution, the extravesical detrusorrhaphy is commonly employed for primary VUR for both unilateral and bilateral cases as well as for those with duplication anomalies.

The greatest advantage to the extravesical approach is that the mucosal layer and inner lumen of the bladder are not violated. This effectively limits perivesical urinary extravasation, gross hematuria, and clot formation. Patients have very few if any bladder spasms and postoperative discomfort is minimized with regional analgesia.³⁶ The absence of a ureteral anastomosis significantly decreases the risk of postoperative obstruction thus no ureteral stenting is performed.

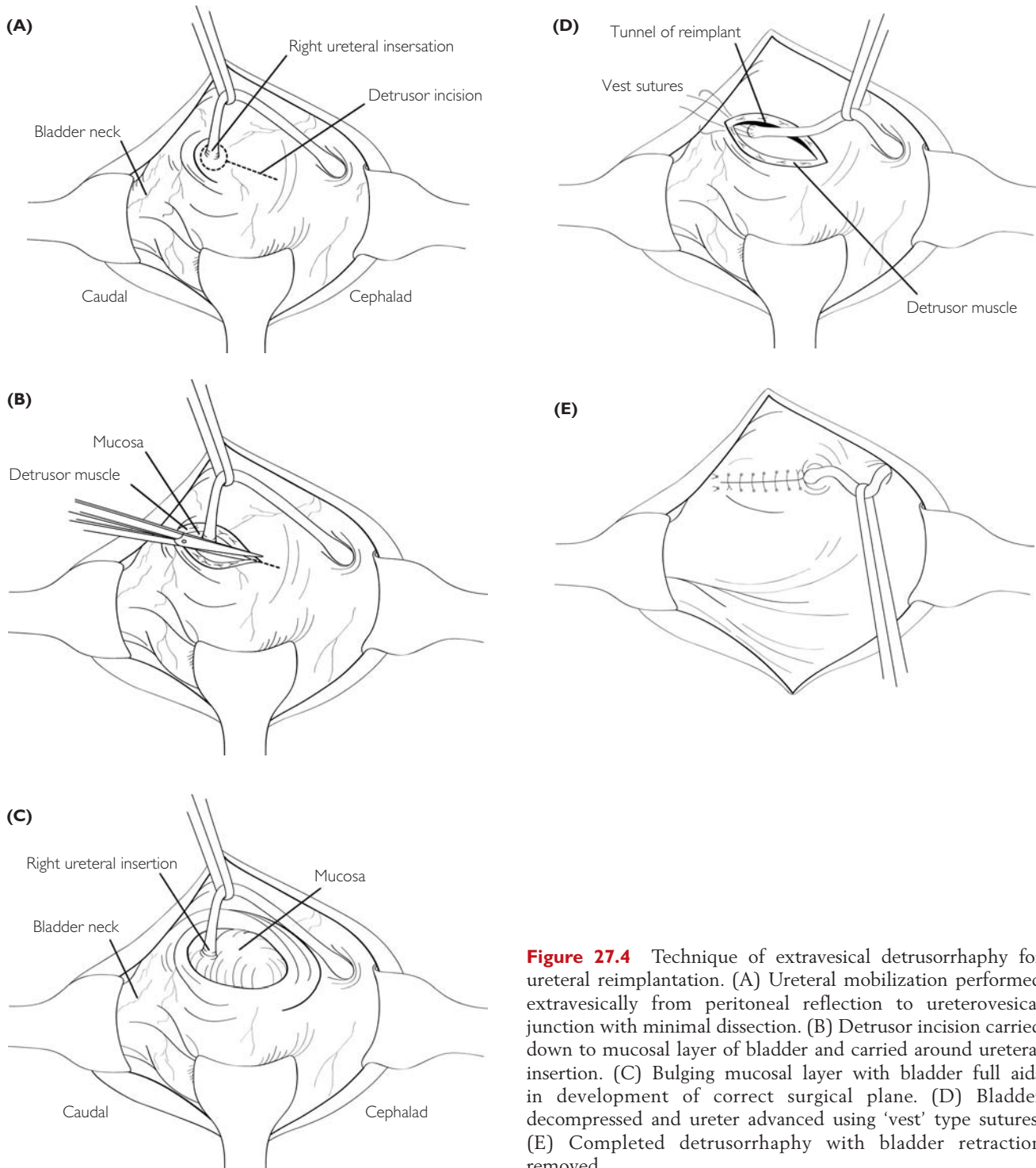


Figure 27.4 Technique of extravesical detrusorrhaphy for ureteral reimplantation. (A) Ureteral mobilization performed extravesically from peritoneal reflection to ureterovesical junction with minimal dissection. (B) Detrusor incision carried down to mucosal layer of bladder and carried around ureteral insertion. (C) Bulging mucosal layer with bladder full aids in development of correct surgical plane. (D) Bladder decompressed and ureter advanced using 'vest' type sutures. (E) Completed detrusorrhaphy with bladder retraction removed.

The main concerns among many surgeons with the bilateral extravesical detrusorrhaphy are the reports of significant postoperative voiding dysfunction and urinary retention.^{37,38} It is postulated that bladder innervation at the trigone can be damaged during bilateral dissection or impaired during lateral bladder retraction, leading to temporary neuropraxia and voiding dysfunction.³⁹ Most patients spontaneously resume complete bladder emptying within 4 weeks of surgery. In our

series, 4% of patients had temporary incomplete bladder emptying and all resolved within 1–3 weeks.⁴⁰ The risk factors may be a younger age at the time of surgery or those with large, poorly emptying bladders prior to surgery.

The technique of extravesical detrusorrhaphy (Figure 27.4) begins with cystoscopy under anesthesia to exclude mucosal inflammation and to assess the position of the ureteral orifices. The presence of an

ectopic ureteral insertion (at or very near the bladder neck) would obviate the use of this technique. Most patients have caudal or epidural analgesia for postoperative pain control. Once the lower abdomen and genitalia are prepped and draped in the supine position, a urethral catheter is placed into the bladder from the sterile field for control of inflation and deflation of the bladder throughout the procedure.

A typical Pfannensteil incision is performed to expose the space of Retzius and a self-retaining retractor (Denis-Brown or Bookwalter) is placed into the incision. The paravesical space is explored, and the bladder is retracted medially. The obliterated umbilical artery is identified and is generally not divided unless additional exposure is required. The retrovesical ureter can be located by identifying ureteral peristalsis, thus minimizing perivesical dissection. Once the ureter is identified extravasically, it is placed on gentle traction with a vessel loop. The ureter is mobilized from surrounding tissue from the peritoneal reflection to the ureteral vesical junction, leaving the periadventitial vascularity intact. The bladder is then optimally distended, and the detrusor muscle is incised cephalad from the ureteral hiatus for a sufficient length to enable a submucosal tunnel length to ureteral inner diameter ratio of approximately 5 : 1.

The muscle fibers are divided with fine curved microscissors down to the mucosal layer, which is not violated. Muscular flaps are mobilized adequately so they can easily be opposed over the ureter. The dissection is carried distally around the ureter caudally until it is only attached to the bladder by mucosal attachments. Retraction sutures on the flaps can be helpful to maximize surgical exposure. The bladder is then emptied, leaving the mucosal trough for the reimplantation. The ureter is advanced and anchored distally with two 4-0 polyglactin 'vest-type' sutures placed in a vertical mattress fashion. The ureter is carefully advanced and the sutures tied under direct vision to avoid angulation. The muscular flaps of the bladder are brought over the ureter and closed with running or interrupted 3-0 polyglactin or polydioxanone sutures.

The bladder is then allowed to retract to its normal position and the ureter is inspected to ensure peristalsis and assess for dilatation. Drains are not used routinely unless significant mucosal tears occur. Rarely, an inadvertent mucosotomy requires closure with a figure of eight 5-0 polydioxanone suture. Reimplantation of a complete ureteral duplication is managed in exactly the same fashion. The two ureters are mobilized together extravasically in their common sheath and reimplanted using the same techniques. Periureteral (Hutch) diverticulae are also managed very efficiently using the

extravesical detrusorrhaphy. Once the detrusor flaps are mobilized and the bladder drained, the mucosa of the diverticulum drops into the bladder along with the rest of the mucosal trough and the detrusor can be closed over the ureter, thus effectively treating the diverticulum without excision.

Postoperatively, the bladder catheter can be removed the next day in a unilateral case and after 2–3 days in a bilateral case. If extensive extravesical dissection was performed or the bladder was very large, thin walled, and floppy, then a longer period of bladder drainage may be considered as well as intraoperative placement of a suprapubic tube to check postvoid residuals. In general, if this is a concern preoperatively or if the patient is under age 1 then an intravesical technique is strongly considered. A renal and bladder sonogram is performed 2 weeks after surgery and then again at approximately 3 months postoperatively. Suppressive antibiotics are generally continued for 3 months after surgery and discontinued if the upper tract imaging is stable and the patient is asymptomatic. A VCUG is performed only if the patient has an episode of clinical pyelonephritis. Long-term follow-up is individualized but it is reasonable to assess renal growth by ultrasound at 1 year after surgery.

In cases of clinical pyelonephritis and a postoperative cystogram showing persistent VUR, initial treatment should be to stabilize the bladder with antibiotic suppression and aggressively treat any voiding dysfunction and/or constipation that may be present. If the VUR persists then treatment options include observation with antibiotic prophylaxis, re-operative ureteral reimplantation, or endoscopic injection of Dx/HA. Success rates of up to 80% have been reported after one injection of Dx/HA after a failed ureteroneocystostomy.⁴¹ This can be technically challenging after a previous cross-trigonal (Cohen) repair but can be facilitated by initially passing an angle-tipped guide wire to straighten out the orifice.⁴² The injection needle can also be placed percutaneously through the suprapubic area into the bladder and manipulated to the correct position at the orifice by the cystoscope. If a repeat open ureteral reimplantation is necessary, an extravesical-intravesical technique (Paquin) can be helpful to obtain adequate ureteral mobilization. Open reimplantation after endoscopic injection can often be successfully performed using an extravesical technique with or without excision of the Dx/HA bleb.⁴³

In conclusion, the management of vesicoureteral reflux is evolving and requires a thoughtful decision-making process with full participation of the parents. It involves an assessment of not only the degree and



Figure 27.5 Ultrasound showing solitary right kidney in patient with vertebral, anal, tracheo-esophageal, and renal anomalies (VATER) syndrome showing severe hydronephrosis.

severity of reflux but also the patient's age, renal status, and clinical course. The preferences of the parents should be strongly considered in deciding among the various medical and surgical treatments. Regardless of the particular technique chosen, it is reassuring that most patients do very well with high success rates and relatively low morbidity.

MEGAURETER

Introduction

The management of primary megaureter has evolved over the years from early surgical intervention^{44,45} to a more conservative initial approach.⁴⁶ The latter entails close clinical and radiographic evaluation as well as antibiotic chemoprophylaxis. The majority of patients do not tend to require surgery, particularly when they are discovered after an evaluation for prenatal hydronephrosis.^{47–51} The initial evaluation is important to make a precise diagnosis and evaluate the degree of risk to the affected renal unit. This includes a thorough history and physical examination along with renal and bladder ultrasonography, voiding cystourethrogram, and diuretic renography to assess split renal function and drainage patterns. Antibiotic chemoprophylaxis is prescribed, and voiding dysfunction is addressed if present. Follow-up radiographic imaging is individualized according to the patient's initial evaluation.

The decision to intervene surgically is often difficult in the young infant with severe hydroureteronephrosis and worsening diuretic renogram. Few series have reported outcomes of megaureter repair in this patient population.^{44,52} In this situation, a low, end cutaneous ureterostomy can be a helpful temporizing measure

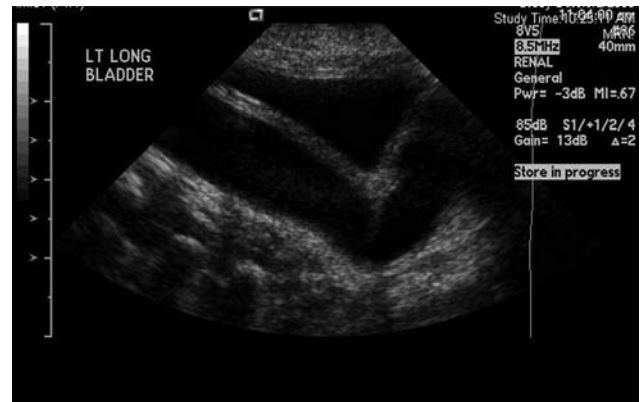


Figure 27.6 Massive ureteral dilatation in same patient with VATER syndrome as Figure 27.5. The patient underwent low end cutaneous ureterostomy.

(Figures 27.5 and 27.6). This procedure is rarely performed but can be useful in the case of a massively dilated ureter in a small infant in which extensive ureteral tailoring and ureteral reimplantation can potentially jeopardize the vascularity of the distal ureter. Urinary diversion and megaureter repair can then be safely deferred until after the age of 1 when the child is older and the reconstruction is more feasible. In some patients, ureteral tailoring will not be necessary for a successful reimplantation.⁵³ At our institution, after diversion only 20% of patients have needed ureteral tapering at the time of reimplantation.⁵⁴

Indications for operative management in an older child after close follow-up include worsening hydroureteronephrosis along with deterioration in renal function and/or a prolonged radiotracer washout pattern in the involved kidney. Additional factors in the decision-making process include the presence of symptoms, UTI, and/or a tense flank mass on physical examination. Ureteral tailoring is indicated if a 5:1 ratio of tunnel length to ureteral diameter cannot be achieved. This can be performed by an excisional⁵⁵ or folding⁵⁶ technique to reduce the caliber of the ureter. Excellent surgical outcomes have been reported in recent series with success rates from 90 to 96%.^{56–58} The investigators in these reports generally performed the ureteral tailoring and subsequent reimplantation through an intravesical approach. There are very few series in the literature that report performing this operation with an entirely extravesical technique, but the results have generally been favorable.^{59–61}

The data from our series comparing extravesical with intravesical techniques for megaureter repair suggested that patients with preoperative high-grade VUR or voiding dysfunction may benefit from an intravesical ureteral reimplantation. Younger patients

appeared to be at a higher risk of having a poor outcome irrespective of technique.⁶²

Surgical intervention

Cystoscopy is generally recommended to assess the intravesical anatomy and rule out an ectopic ureter or ureterocele which may change the management. Regional analgesia with a caudal block or epidural catheter is helpful for a smooth postoperative course. The surgical approach to megaureter repair is typically through a low, transverse abdominal Pfannenstiel incision. The space of Retzius is entered as with typical ureteral reimplantation, and exposure is obtained with a self-retaining retractor. The bulging and dilated ureter is identified extravesically, and gently placed on traction with a vessel loop. The ureter is mobilized to the ureterovesical junction where it is divided and the hiatus oversewn. A 4-0 polyglactin stay suture is placed on the distal edge of the ureter. The ureter is fully mobilized to the extent of the exposure at the peritoneal reflection. In a male, it is imperative to completely identify the vas deferens as it courses over the ureter to avoid iatrogenic injury.

Once the ureter is mobilized and decompressed, the decision is made whether to proceed with extensive ureteral tailoring. If a sufficient tunnel length to diameter ratio of at least 5:1 cannot be achieved, then the ureter must be tapered. The technique most often employed at our institution involves ureteral excision using a free-hand technique without Hendren clamps. The folding technique (Kalicinski) has its advocates but tends to leave a bulky mass within the bladder.^{56,63} A 10 or 12 Fr catheter is placed within the lumen of the ureter and 4-0 polyglactin sutures are placed to mark the tissue to be excised. It is important to realize that only the intramural portion of the ureter needs to be tapered. An incision is made longitudinally along the adventitia and flaps are developed under the adventitia to the edge demarcated by the stay sutures. The intervening strip of ureteral mucosa and serosa is then excised with fine microscissors. The full thickness of the ureter is re-anastomosed with a running, locking 6-0 or 7-0 polydioxanone suture and the adventitia is re-approximated with interrupted 5-0 polyglactin suture.

The ureter may then be reimplanted using an extravesical technique by creating a detrusorrhaphy as described above for primary VUR. A small defect in the distal extent of the mucosal trough is made and a sutured ureterovesical anastomosis performed with interrupted 5-0 polyglactin suture over a 6 or 8 Fr double-J ureteral stent. The muscle flaps are then



Figure 27.7 Technique of endoscopic injection of dextranomes/hyaluronic acid copolymer (STING procedure). Figure used with permission from the Q-Med Corporation®, Uppsala, Sweden



Figure 27.8 Ultrasound showing severe left-sided hydronephrosis from obstruction at ureterovesical junction.

closed as previously described. Conversely the bladder may be opened via a midline cystotomy and an intravesical cross-trigonal reimplantation performed. A perivesical drain is typically employed and a urethral catheter left indwelling. Cystoscopy is then performed as an outpatient 4 weeks postoperatively to remove the ureteral stent. Imaging with renal and bladder ultrasound 2 weeks after stent removal is helpful to assess for improvement in hydronephrosis and assess for perivesical fluid collections. A VCUG can be helpful to rule out postoperative de novo VUR but may not be necessary in an asymptomatic patient, particularly if male.

The complication rates in most reported series are low but may include persistent obstruction, UTIs, urinary extravasation, and/or low grade VUR. In our series with a strict definition of a successful outcome (improved hydronephrosis and no VUR), the success rate was 86% for intravesical and 76% for extravesical reimplantation (Figures 27.8 and 27.9). Most of those with adverse outcomes had low grade VUR that was managed with either observation or endoscopic injection. Only 3% of patients had persistent hydronephrosis

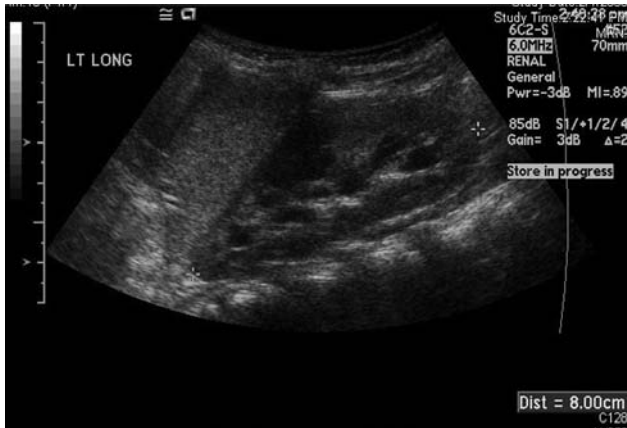


Figure 27.9 Postoperative ultrasound of same kidney 1 year after megaureter repair.

and an underlying bladder dysfunction was felt to be responsible in those cases.

In conclusion, the management of primary obstructive megaureter often entails close non-surgical observation after a thorough evaluation of the anatomy and drainage of the affected kidney. If surgical intervention is required due to symptoms or progressive renal injury, ureteral reimplantation with extensive ureteral tailoring is a highly successful operation with low morbidity. Outcomes may be improved using an intravesical reimplantation technique in cases of young patients or those with pre-existing voiding dysfunction (Figure 27.9).

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28 Modern staged repair of exstrophy/epispadias

J Todd Purves and John P Gearhart

Classic bladder exstrophy represents one of the most challenging urologic birth defects in reconstructive surgery. It manifests as a ventral midline defect in the abdominal wall musculature, bladder, urethra, and external genitalia, along with diastasis of the pubic symphysis and external and inferior rotation of the pelvic bones. Bladder exstrophy has been classified as part of the exstrophy/epispadias complex which includes primary epispadias, cloacal exstrophy, and other rare variants.

Population based studies demonstrate the incidence of bladder exstrophy to be between 2.15 and 3.3 cases per 100 000 live births.¹ Contrary to prior surgical series, the male to female ratio appears to be approximately even.

Primary epispadias consists of a closed bladder and abdominal wall with a dorsally displaced urethra that may be located anywhere between the bladder neck and the glans, in males, or the distal urethra, in females. Males also demonstrate some degree of dorsal chordee that require repair at the time of reconstruction. More severely affected patients, in whom the defect involves the bladder neck or significant portions of the urethra, will be incontinent and ultimately require bladder neck reconstruction.

INITIAL MANAGEMENT

With the widespread use of prenatal ultrasound screening, diagnosis of exstrophy is more commonly being made prior to birth.² Ideally, these children should be delivered at centers experienced with the exstrophy condition so that parents may be counseled properly and appropriate management delivered expeditiously. In cases where this is not possible, or when the diagnosis is made at birth, protecting the exposed bladder is paramount. Instead of placing an umbilical clamp, which can be a potential source of trauma, the stump should be tied off with a 2-0 silk. The bladder surface should be covered with a non-adhesive, occlusive dressing such as plastic wrap. At each diaper change, the area should be rinsed with sterile saline and the dressing changed.

Evaluation prior to surgery includes a general physical and cardiopulmonary assessment. Ultrasonography and radionuclide studies can evaluate renal structure, function, and drainage prior to bladder closure.

The size and functional capacity of the bladder are critical to the success of a functional closure and need to be ascertained prior to surgery. Examinations must be done under anesthesia because a significant amount of bladder may be discovered behind the fascia when the infant is completely relaxed. Immediate bladder closure is appropriate when the estimated capacity is greater than 5 ml and the tissue is elastic and demonstrates good contractility.

Despite the fact that early/immediate bladder closure portends better outcomes, this is not always possible when the bladder is too small or the tissue is of poor quality. In these cases it is best to delay any procedure for 4–6 months with the hope that the bladder will develop sufficiently for a functional closure. During the waiting period, meticulous care of the exposed bladder surface, as described above, is essential. Since the decision to delay closure has irreversible consequences on the ultimate results, it should be made by a surgeon with considerable experience.

SURGICAL TECHNIQUES

The primary objectives of the modern surgical management of classical bladder exstrophy are a secure abdominal closure, reconstruction of a functional and cosmetically acceptable penis in the male or female external genitalia in the female, and urinary continence with the preservation of renal function. Currently, these objectives can best be achieved with newborn primary bladder and posterior urethral closure, early epispadias repair at approximately 6 months of age, and, finally, bladder neck reconstruction with ureteral reimplantation when the bladder reaches an appropriate volume for an outlet procedure and the child is maturationally ready to participate in a voiding program.

In highly select cases, bladder closure and epispadias repair can be combined in the newborn period, but

only by experienced exstrophy surgeons as complications can be significant.

Pelvic osteotomy

At our institution, combined bilateral anterior innominate and vertical iliac osteotomies³ are performed on all patients older than 72 hours, as well as those younger than 72 hours who either have a pubic diastasis greater than 4 cm or whose pelvis is not sufficiently malleable that the pubic bones can be easily brought together in the midline. If there is any doubt regarding whether to perform osteotomies, we err on the side of caution and perform them at the time of initial closure. Experience with failed exstrophies has shown that omission of the osteotomies leads to higher rates of dehiscence and unsuccessful closure.⁴

Antibiotics, usually ampicillin and gentamicin, are given prior to surgery and then continued for 10 days postoperatively. After the exposed bladder is washed and cleaned with povidone-iodine, the preparation is extended from the level of the nipples to the knees. The posterior body wall and hips must be accessible during the procedure, so we include preparation from the base of the scapula to the buttocks and then to the posterior aspect of the popliteal fossa. Application of an adhesive surgical dressing to the anus prevents stool contamination.

With the patient in a supine position, the pelvis is exposed from the iliac wings inferiorly to the pectineal tubercle and posteriorly to the sacroiliac joints. After carefully elevating the periosteum and sciatic notch, a Gigli saw is used to create a transverse innominate osteotomy exiting anteriorly at a point halfway between the anterior-superior and anterior-inferior spines (Figure 28.1). The posterior iliac osteotomy is performed using an osteotome to create a closing wedge vertically and just lateral to the sacroiliac joints. Leaving the proximal posterior iliac cortex intact, this wedge acts as a hinge to facilitate the closure of the pelvic bones.

Older children should have two external fixator pins placed in the inferior osteotomized segment and two more in the wing of the ilium superiorly. Newborns, who have a paucity of cancellous bones, should only have one pin each placed inferiorly and superiorly in each bone wing. Intraoperative radiographs are obtained to confirm pin placement and soft tissues are closed. The urologic procedure is performed and then the pubic symphysis is coapted with a horizontal mattress suture of No. 2 nylon.

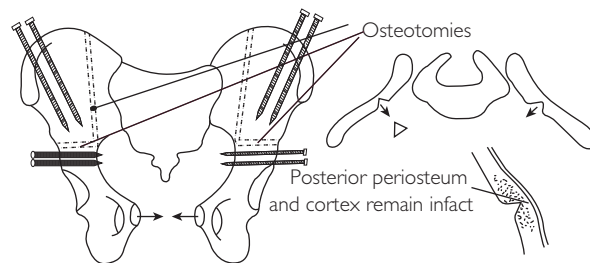


Figure 28.1 Combined transverse anterior innominate and anterior vertical iliac osteotomy. From reference 5, with permission.

Bladder, urethral, and abdominal wall closure

The technique of initial bladder closure is depicted in Figure 28.2. An incision that outlines the bladder template and incorporates the umbilicus at the cephalad aspect is made. At its caudal aspect, a 2 cm wide strip of mucosa is created that extends from the distal trigone to below the verumontanum in the male or to the vaginal orifice in the female. Usually in the male, a transverse incision of the urethral plate is not performed. In cases where the urethral groove is so short that ultimate penile length will be inadequate or where dorsal angulation will be produced, penile lengthening is performed by transversely incising the urethral plate and filling the gap with rotational flaps of paraexstrophy skin. While occasionally necessary this maneuver does carry a risk of ischemia and stricture formation, and limits the available tissue for future urethral reconstruction. It should therefore be done only when the urethral plate is foreshortened as to prevent deep placement of the posterior vesicourethral unit.

Dissection in the plane between the bladder and the rectus fascia begins cephalad to the umbilicus and is carried down caudally, taking time to doubly ligate and divide the umbilical vessels. The critical goal at this point of the procedure is to enable the reconstructed bladder to be placed deep within the pelvis. This starts by freeing the peritoneum from the dome of the bladder. As the work continues caudally, a transverse bar of tissue, representing the urogenital diaphragm, is encountered. A double pronged skin hook can provide lateral traction on the pubic bones and accentuate these fibers. Placing gentle traction on the glans demonstrates the insertion of the corporal body on the lateral inferior aspect of the pubis. Radical incision of these fibers between the bladder neck, posterior urethra, and pubic bone is essential for allowing proper placement of the vesicourethral unit deep into the pelvis.

After placement of a suprapubic cystostomy tube and ureteral stents, the bladder mucosa and muscle are closed well onto the penis in the anterior midline. The opening

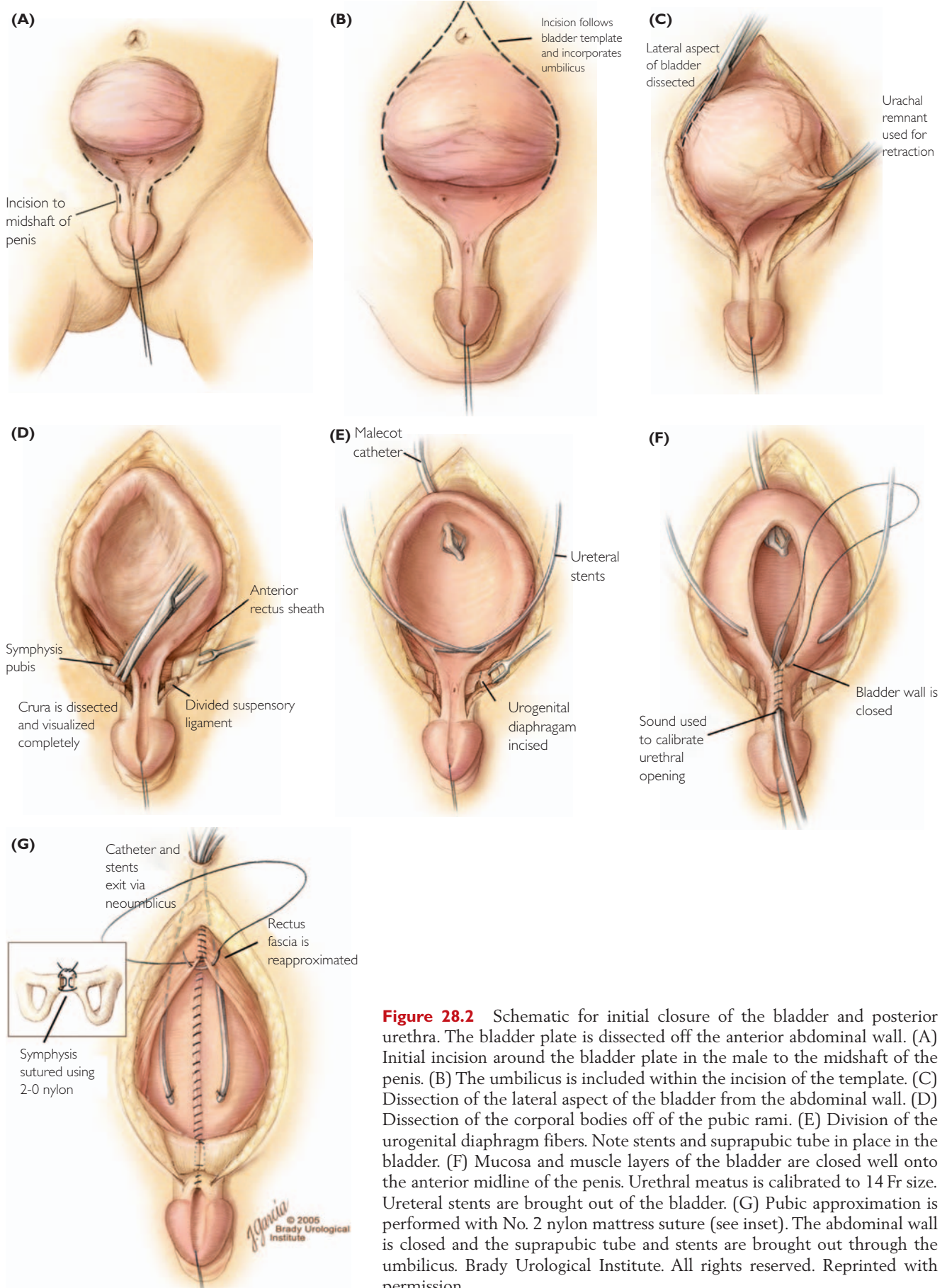


Figure 28.2 Schematic for initial closure of the bladder and posterior urethra. The bladder plate is dissected off the anterior abdominal wall. (A) Initial incision around the bladder plate in the male to the midshaft of the penis. (B) The umbilicus is included within the incision of the template. (C) Dissection of the lateral aspect of the bladder from the abdominal wall. (D) Dissection of the corporal bodies off of the pubic rami. (E) Division of the urogenital diaphragm fibers. Note stents and suprapubic tube in place in the bladder. (F) Mucosa and muscle layers of the bladder are closed well onto the anterior midline of the penis. Urethral meatus is calibrated to 14 Fr size. Ureteral stents are brought out of the bladder. (G) Pubic approximation is performed with No. 2 nylon mattress suture (see inset). The abdominal wall is closed and the suprapubic tube and stents are brought out through the umbilicus. Brady Urological Institute. All rights reserved. Reprinted with permission.

should be of sufficient size to comfortably accommodate a 10–12 Fr sound. When possible, the posterior urethra and bladder neck are buttressed with a second layer of local tissue. The repair is suspended to the rectus fascia. The pubic symphysis is reapproximated, as described in the previous section, and the abdominal wall is closed. A V-shaped flap of skin is tacked down to the abdominal fascia at the anatomic point of the umbilicus and the drainage tubes are brought out through this orifice. The urethra is left unstented to avoid necrosis with accumulation of secretions in the neourethra.

Postoperative management

Patients who have undergone formal osteotomies are placed in modified Buck's traction for 4–6 weeks and the external fixator is kept for approximately 6 weeks until a radiograph shows adequate calculus at the site of osteotomy. Radiographs are also obtained 7–10 days postoperatively, and if the pubic diastasis is not completely reduced, the fixator bars are gradually reapproximated.⁶ Newborns undergoing repair without osteotomy may be immobilized with modified Bryant's traction for 4 weeks. Given the high rate of failure and complications, spica cast and 'mummy wrapping' techniques are not recommended.

Four weeks after surgery, a voiding trial is performed by clamping the suprapubic tube and measuring residual urine. Calibration of the bladder outlet with a sound or catheter should demonstrate free drainage and an ultrasound of the upper tracts is performed to ascertain the status of the kidneys and ureters. Prior to removing the suprapubic tube, urine specimens are sent for culture and any infections are treated with appropriate antibiotics. Since all exstrophy patients will have vesicoureteral reflux after closure, prophylactic antibiotics are started immediately.

Gravity cystograms under anesthesia are obtained annually to assess vesicoureteral reflux and estimate bladder capacity. Four to five years may be required to achieve the goal capacity for bladder neck reconstruction, which is 100 ml.⁷ However, if the bladder does not reach a capacity of 30 ml by age 1–2 years, the likelihood of ever reaching an appropriate volume is diminished and this should be discussed with the parents.

Epispadias repair

The purpose of epispadias repair is to reconstruct a functional and cosmetically acceptable penis. Apparent lengthening of the penis can be obtained by lengthening

the urethral groove and correcting the dorsal chordee. Due to the inherent 50% decrease in length of the corpora cavernosa in these patients, no surgical technique can provide a true increase in the length of the penis.⁸ This second stage of the modern staged repair is typically performed when the child is 6–12 months of age, resulting in an increased outlet resistance which has been shown to promote further bladder development.

Preoperative administration of testosterone increases the corporal length and availability of penile skin to aid in reconstruction. This regimen consists of intramuscular injections of testosterone enanthate in oil, 2–3 mg/kg, at 5 weeks and 2 weeks before surgery.

At our institution, the method of choice for epispadias repair is the modified Cantwell-Ransley procedure (Figure 28.3). After placing a traction stitch in the glans, parallel incisions are made at the lateral aspects of an 18 mm wide strip of urethral mucosa extending from the prostatic urethral meatus to the distal tip of the penis. The urethral plate is advanced by making a deep vertical midline incision at the distal urethra and closing it transversely (IPGAM). Thick glandular flaps are created bilaterally, adjacent to the urethral strip. A Z-incision facilitates division of the suspensory ligaments and excision of scar tissue from the prior bladder closure.

Degloving of ventral skin proceeds to the level of the scrotum while preserving the mesentery of the urethral plate. The corpora are freed up with the dissection starting ventrally, on the surface of Buck's fascia, and proceeding through to the dorsal penis between the corpus spongiosum and the corporal body. With loops aiding in lateral traction of the corpora, dissection extends proximally to free the urethral plate to the level of the prostate. The urethral plate is then mobilized distally past the junction between the corpora and glans to allow rotation of the corporal bodies over the urethra. Note that the distal 1 cm of the urethral plate is left intact, in contrast to the penile disassembly technique.

Medial rotation of the corporal bodies over the urethral plate allows for ventral positioning of the neourethra and corrects the dorsal chordee in the majority of cases. In unusual circumstances where this maneuver is not sufficient, the neurovascular bundles are carefully dissected from the corporal bodies prior to rotation. Diamond shaped incisions in the corpora are made at the point of maximum deflection and then sutured to each other after rotation to enhance straightening.

Whether corporal incisions are required, the neourethra is closed in linear fashion over an 8 Fr silicone stent and corporal bodies are closed over it. Closure of the glans wings and epithelium completes the urethral

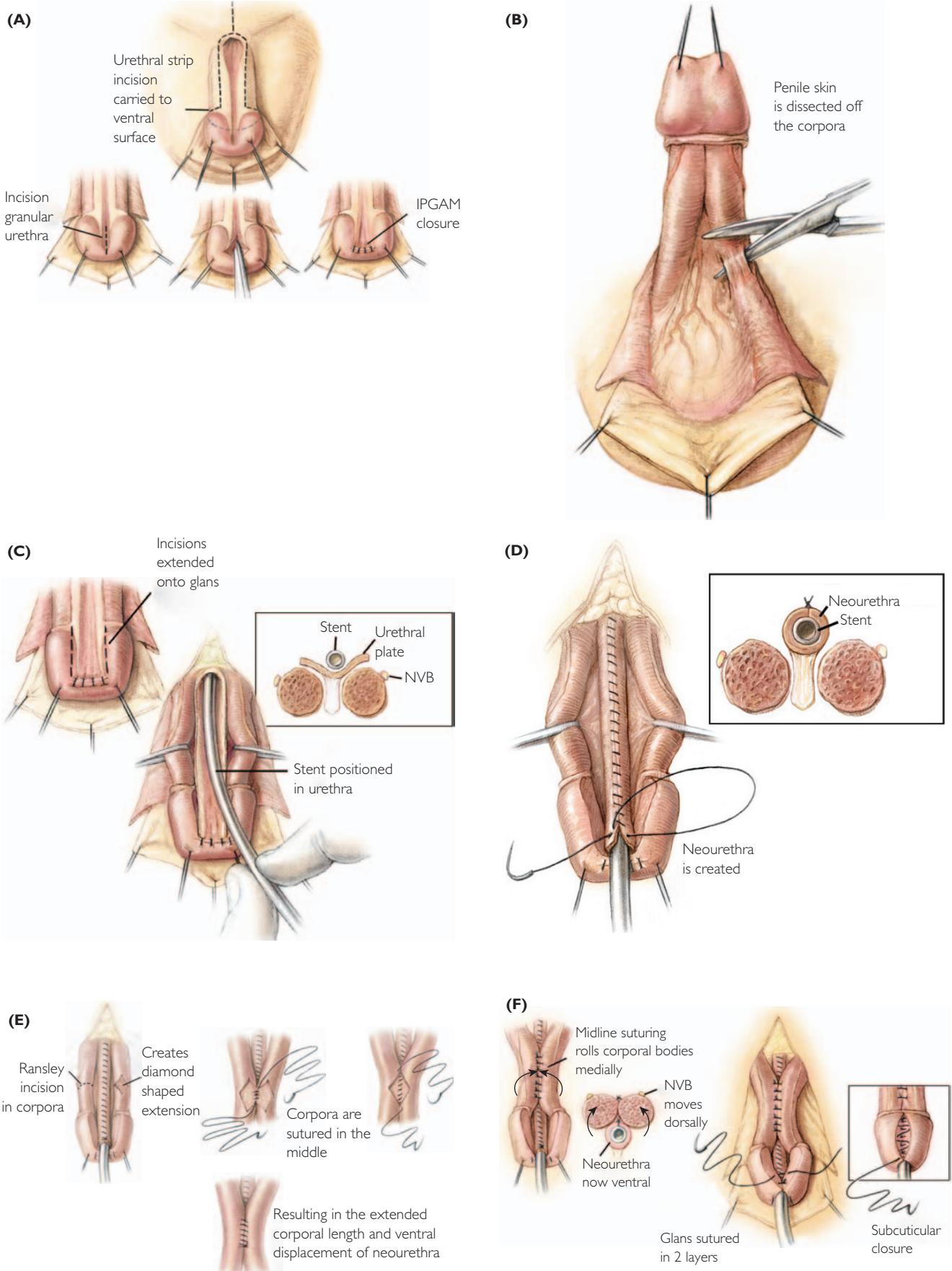


Figure 28.3 (Continued)

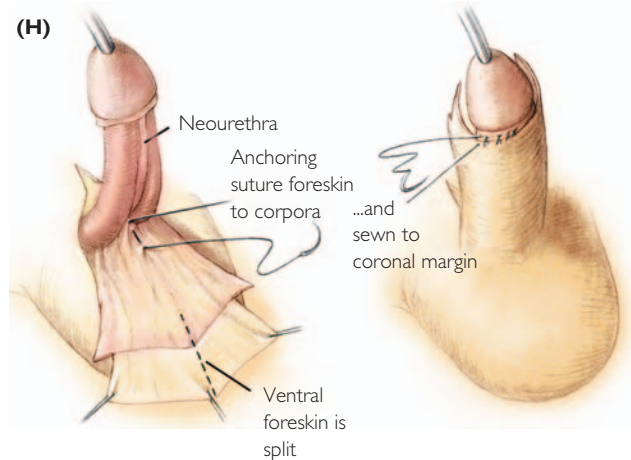
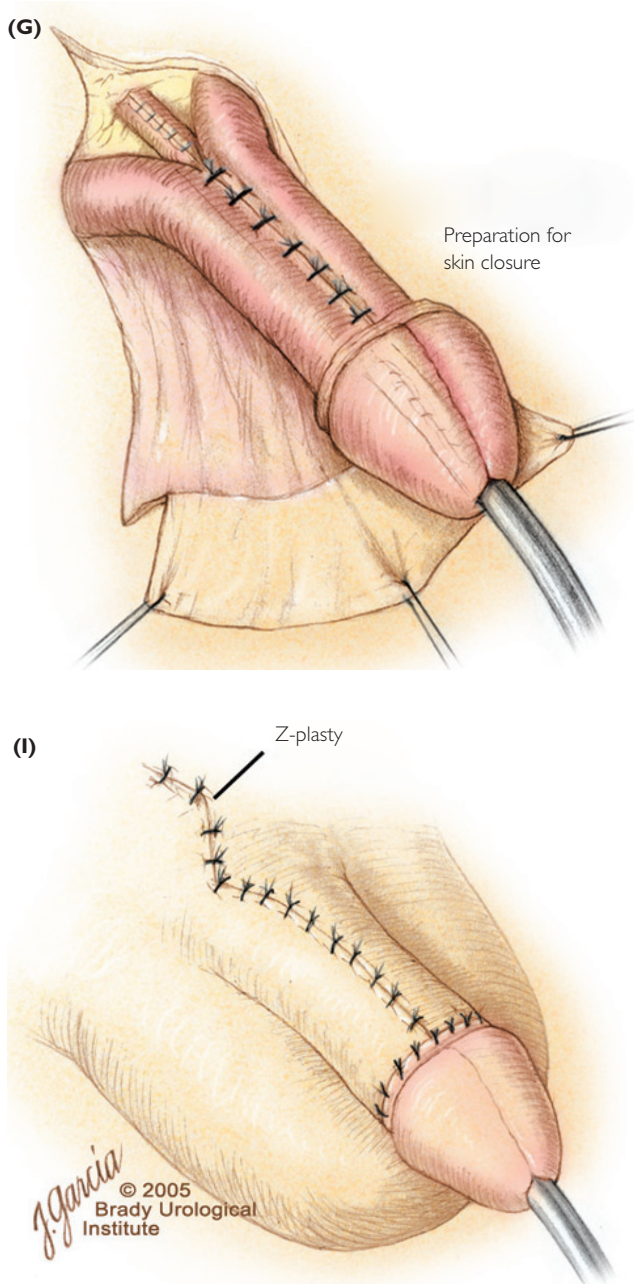


Figure 28.3 Modified Cantwell-Ransley epispiadias repair. (A) Initial incision extends around the urethral plate and the coronal sulcus. A deep vertical midline incision in the midline of the distal urethra (IPGAM) is closed horizontally with 6-0 polyglycolic acid suture to bring the urethral meatus to the tip of the glans. (B) Degloving the ventral penile skin. (C) The corpora are dissected off the urethral plate and parallel incisions extend into the glans to create glans wings. Care is taken to protect the neurovascular bundles (NVB), located laterally (inset). (D) The urethra is tubularized over an 8 Fr stent using a continuous running suture of 6-0 polyglycolic acid. (E) Approximation of the corpora with 5-0 polydioxanone suture using incisions in the corpora if indicated for penile straightening. (F) Corpora rotated medially and approximated above the urethra with 4-0 polyglycolic acid suture to provide an anatomically ventral location of the urethra (see inset). Two layer reconstruction of the glans using subcuticular sutures of 5-0 polyglycolic acid and then 6-0 polyglycolic acid to close the epithelium. (G) Preparation for skin closure. (H) Suture is placed at the base of the penis to locate the foreskin on the shaft of the penis as well as to provide an area of distinction between the penis and scrotum. Foreskin is split ventrally and then sewn to the coronal sulcus. (I) Completion of the repair with resurfacing of the penis and use of a proximal Z-plasty incision to provide downward penile deflection. Skin approximation is accomplished with 5-0 or 6-0 polyglycolic acid sutures. The urethral stent is left indwelling for 10–12 days. Brady Urological Institute. All rights reserved. Reprinted with permission.

reconstruction. The ventral skin is brought up and sutured to the ventral edge of the corona, using flaps to close the dorsal surface, and the Z-plasty at the base of the penis is closed. The 8 Fr silicone stent is left in the neourethra for 10–12 days.

Bladder neck reconstruction

The goal of bladder neck reconstruction is to allow voluntary voiding with continence. Children must be mature enough to participate in a voiding program, typically 4–5 years of age. Recent data from our institution⁷ suggest that patients with a bladder capacity of

100 ml or larger are more likely to be completely dry after the procedure.

As illustrated in Figure 28.4, a modified Young-Dees-Leadbetter bladder neck reconstruction is performed concurrently with a cephalotrigonal ureteral reimplant. The bladder is opened through a vertical midline incision with a transverse extension caudally. Although a Cohen transtrigonal technique can be used, we prefer a cephalotrigonal reimplant so that a larger portion of the trigone can be used for the continence procedure. After stenting the ureters, a midline posterior strip of mucosa between 15 and 18 mm wide and 30 mm long is selected that extends from the midtrigone to the prostate or posterior urethra. Bilateral mucosal

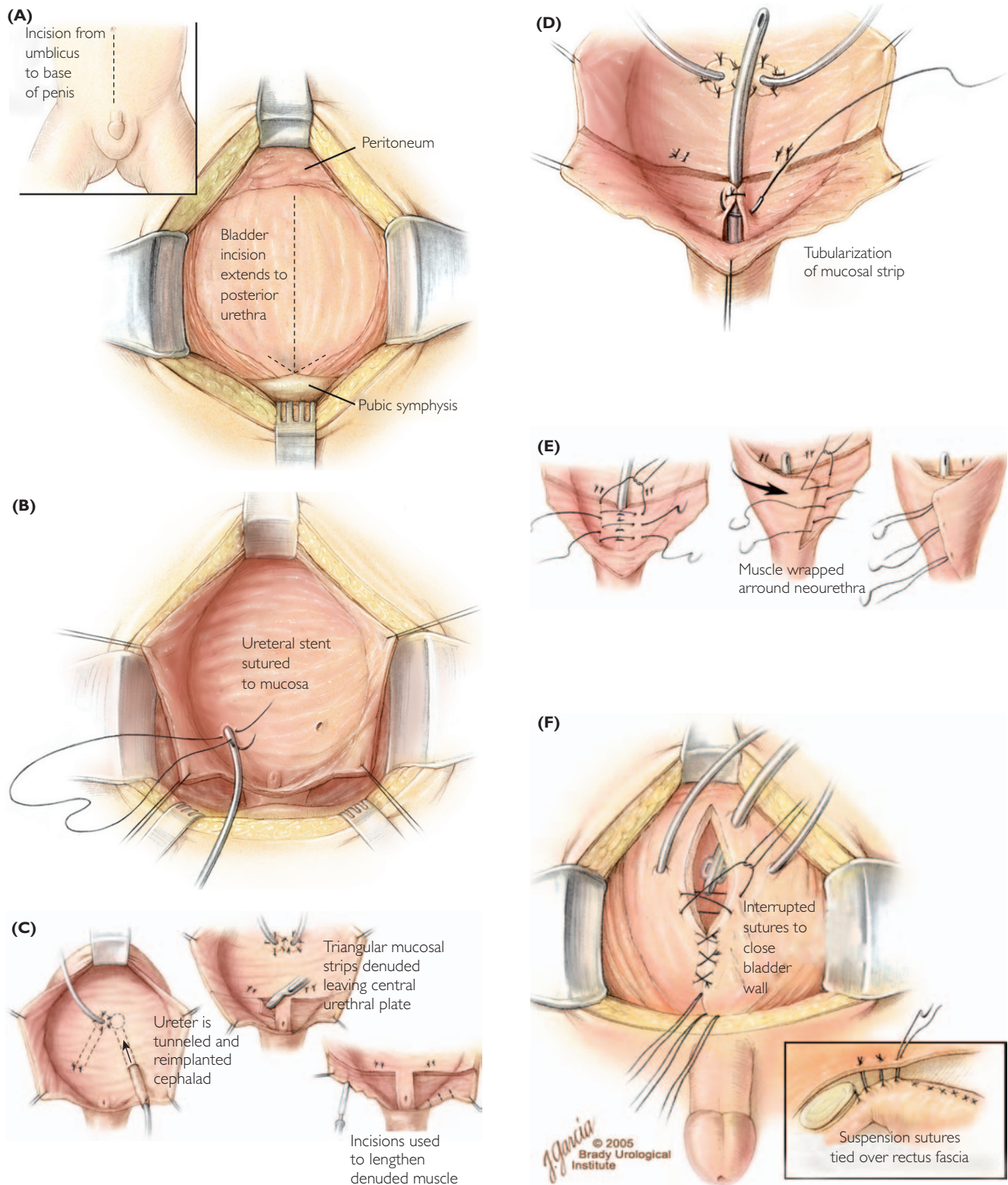


Figure 28.4 Modified Young-Dees-Leadbetter bladder neck reconstruction. (A) Vertical cystotomy with distal transverse extension where the bladder and posterior urethra are under the pubic bar. (B) Ureteral stents are placed and then secured to the bladder mucosa. (C) Ureters are identified, mobilized, and reimplanted in a cephalotrigonal fashion. Segments of mucosa are excised from either side of a median strip (1.5 cm × 3 cm) that will become the neourethra. Short incisions in the muscle permit a more cephalad reconstruction. (D) Urethra is tubularized using a continuous running suture of 4-0 polyglycolic acid. (E) Posterior urethra and bladder neck are reconstructed. The denuded muscle flaps are brought together in a double-breasted fashion over the neourethra using 3-0 polydioxanone suture. (F) Bladder closure is completed and the repair is suspended to the rectus fascia (see inset). Suprapubic tube and stents are left in place; the urethra is left unstented.

Table 28.1 Continence rates after exstrophy closure

Series	Patients (n)	Prior closures	Osteotomy	Outcome
Chan et al ⁹	65	Primary	Not reported	77% completely dry 91% socially continent 3% further reconstruction
Gearhart et al ⁷	67	Primary	18/67	70% dry, voiding per urethra 10% socially continent 10% required diversion 10% incontinent, pending further surgery
Oesterling et al ¹¹	144	Primary (81/144) Following failed primary repair (49/144)	Not reported	92% socially continent 55% socially continent 6% diversion
Husmann et al ¹⁰	80	Primary	41/70 (age <1 year) 10/10 (age >1 year)	Age <1 year, + osteotomy 73% socially continent Age >1 year, + osteotomy 60% socially continent Age <1 year, – osteotomy 59% socially continent

Social continence, dry periods of at least 3 hours during the day and dampness at night.

flaps are created on either side of the planned neourethra. Application of 1:200 000 epinephrine soaked sponges helps control bleeding and aid in the visualization of the denuded area. Multiple small incisions on the free edge bilaterally allow for a more cephalad reconstruction. The basic premise, then, is to create a mucosa-lined tube inside a well vascularized funnel that narrows from its junction with the floor of the bladder as it extends caudally. The edges of the mucosa are closed with interrupted stitches and the adjacent muscle flaps, which are denuded but not incised, are overlapped and sutured. This provides reinforcement of the bladder neck and urethral reconstruction. An 8 Fr urethral stent may be helpful when used as a guide during the creation of the urethra but should be removed after completing the reconstruction.

Postoperative management

Ureteral stents are brought out through the wall of the bladder, and a suprapubic tube is left indwelling for bladder drainage. At 3 weeks postoperatively, the suprapubic tube is clamped and the patient undergoes a voiding trial. Initially, the tube should not be clamped for over 1 hour. If voiding does not occur, an 8 Fr Foley catheter is placed under anesthesia. This is left in place for 5 days; it is then removed and another voiding trial is begun. Some children may require several catheter placements before voiding is initiated. After the child can empty the bladder satisfactorily, the suprapubic tube is removed. Frequent bladder and renal ultrasonography is required

in the first few months after bladder neck repair. Patients are maintained on prophylactic antibiotics until they demonstrate adequate bladder emptying and imaging studies show resolution of reflux.

RESULTS

Success with regards to bladder exstrophy repair is defined as a reconstruction that remains intact with proper structural anatomy and ultimately allows for the adequate storage of urine with ability to void. Several series,^{4,9–11} summarized in Table 28.1, have shown that attaining these goals depends, in part, on the success of the initial closure, inclusion of osteotomy, and the timing of the procedure. Not only do patients with a successful initial closure have earlier onset of continence, but they also have higher rates of continence as an end-point. A series by Gearhart et al⁴ showed that patients undergoing multiple closures had decreasing likelihood of dryness as a function of the number of procedures required. Interestingly, they also found that most patients referred for failed closure had not undergone osteotomy at the time of the initial surgery. Given the importance of a proper initial repair, and the impact of osteotomy on the success of this repair, we believe that concurrent performance of pelvic osteotomy is highly recommended unless deemed otherwise by an experienced exstrophy surgeon.

Timing of the primary functional closure ideally occurs within the first 72 hours of life when the pelvic bones are more malleable and may, in some cases, be

easily reapproximated without a pelvic osteotomy. Early closure limits the amount of trauma to the exposed bladder surface and, through bladder cycling, may contribute to enhanced bladder growth. As Husmann et al¹⁰ have shown, the rate of future bladder augmentations increases from 10 to 40% when the procedure is delayed beyond more than 1 year of age. This is not to say that a delayed repair has no clinical role. If the bladder is too small or inelastic, prematurely performing surgery carries a greater risk of dehiscence and poor functional outcome. Therefore, protecting the bladder and allowing 4–6 months of development to adequate size is a safer option and children who develop adequate bladder templates in this period ultimately attain dryness without augmentation approximately 50% of the time. In uncommon cases where the bladder does not develop sufficiently, we proceed with urinary diversion via a colon conduit. This protects the kidneys and allows for the possibility for undiversion at a later date.

Regardless of the repair chosen in the newborn, a successful primary closure of a good size bladder template remains the single most important predictor for urinary continence and ability to void.

While we have focused on the surgical aspects of exstrophy management, a final emphasis must be placed on a multidisciplinary approach with support from pediatric orthopedists, anesthesiologists, psychiatrists, nurses, and social workers who all have experience and interest in dealing with bladder exstrophy.

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29 Rationale for use: complete primary exstrophy repair technique

Richard W Grady

We typically perform the complete primary repair of exstrophy (CPRE or Mitchell technique) in the newborn period (Figure 29.1). Primary reconstruction in the newborn period is technically easier than when performed at a later stage. It also offers theoretical advantages observed with normal bladder development that may improve the potential for urinary continence. The bony pelvis also remains pliable in the newborn period so that osteotomies may be avoided in some cases. However, we favor the use of osteotomies in most patients and suggest that osteotomies be used in conjunction with exstrophy closure if at all in doubt.¹ Neonatal closure employing the CPRE technique optimizes the chance for early bladder cycling which may maximize the potential for bladder development.

The complete primary repair technique allows for movement of the bladder, bladder neck, and urethra posteriorly. This positions the proximal urethra within the pelvic diaphragm in a more anatomically normal position to take advantage of the pelvic muscles and support structures in securing urinary continence. Posterior positioning of the bladder neck and urethra also helps to reapproximate the pubic symphysis and the muscular pelvic diaphragm.

By separating the urethra from its attachments to the underlying corporal bodies and pelvic diaphragm, the urethra is free to move posteriorly. Left attached, the urethra will be tethered anteriorly, preventing posterior placement of the proximal urethra and bladder neck in the pelvis. Tension reduction increases the success of initial primary bladder closure. It also reduces the tension on the corporal bodies that contributes to dorsal chordee and deflection in males with exstrophy/epispadias. Combining the epispadias repair with primary closure allows for the most important aspect of primary closure – division of the intersymphyseal ligament or band (anterior portion of the pelvic diaphragm) located posterior to the urethra in these patients. This allows for posterior positioning of the bladder, bladder neck, and urethra in a more anatomically normal position. The goal of the complete primary repair approach is to combine the stages of staged anatomic reconstruction in a single operation (i.e. bladder closure, epispadias repair, and achievement of urinary continence).



Figure 29.1 Male newborn with exstrophy.

PREOPERATIVE CARE

After delivery, the umbilical cord should be ligated with silk suture rather than a plastic or metal clamp to prevent trauma to the exposed bladder plate. We believe it is important to protect the exstrophic bladder by whatever means are available. We prefer hydrated gel dressings such as Vigilon®. This type of dressing is easy to use, keeps the bladder plate from desiccating, and stays in place to allow handling of the infant with minimal risk of trauma to the bladder. The exposed bladder may be covered with plastic wrap as an acceptable alternative. Dressings should be replaced daily and the bladder should be irrigated with normal saline with each diaper change. Other authors have advocated the use of a humidified air incubator to minimize bladder trauma.²

We also support the recommendations of other investigators including the routine use of:

- 1 Intravenous antibiotic therapy in the pre- and postoperative period. This decreases the chance of infection.
- 2 Preoperative ultrasonography to assess the kidneys and to establish a baseline examination for later ultrasonographic studies.
- 3 Preoperative spinal sonographic examination if sacral dimpling or other signs of spina bifida occulta are noted on physical examination.
- 4 Pelvic computed tomography (CT) with three-dimensional reconstructions to assess pubic diastasis (minimally a kidney, ureter and bladder [KUB]).²

OPERATIVE CONSIDERATIONS

We perform primary exstrophy closure using general inhalation anesthesia and typically avoid the use of nitrous oxide during primary closure since it may cause bowel distention, which decreases surgical exposure during the operation and may increase the risk of wound dehiscence. Some authors advocate the use of nasogastric tube drainage to decrease abdominal distention in the postoperative period.³ We have not routinely used nasogastric suction but do routinely use a one-time caudal block to reduce the inhaled anesthetic requirement during the operation.

For patients older than 3 days, or newborns with a wide pubic diastasis, we perform anterior iliac osteotomies. Osteotomies assist closure and enhance anterior pelvic floor support, which may improve later urinary continence.^{4,5}

Factors that are important in the operative period include:

- Use of osteotomies in selected cases and for newborn closures more than 24–48 hours after birth
- Ureteral stenting catheters placed intraoperatively for use in the postoperative period to divert urine
- Avoidance of abdominal distention
- Use of intraoperative antibiotics.^{6,7}

POSTOPERATIVE CARE

Postoperatively, the child should be immobilized to decrease lateral stresses on the closure after CPRE. Immobilization may be accomplished using a variety of techniques. We have used Spica cast immobilization at our institution consistently over the past 12 years (Figure 29.2). We apply the cast for 3–4 weeks. The cast helps prevent external hip rotation and optimizes pubic apposition and facilitates early discharge and home care. Modified Buck's traction has been used by many groups for a period of 3–4 weeks. A posterior



Figure 29.2 Spica cast immobilization.

lightweight splint can be used in newborns when the child is out of traction to facilitate home care and early removal of traction. We have stopped using Buck's traction because Spica casts are easier for the families to care for at home. External fixation devices have also been advocated by several centers and provide effective immobilization. Fixator pins for these devices should be cleaned several times a day to reduce the chance of infection. Internal fixation may be necessary in older patients and is regularly used at some institutions to immobilize children after exstrophy reconstruction. 'Mummy wrapping' may be unreliable, and its use has been discouraged by some clinicians.³

Because of the high incidence of vesicoureteral reflux, we prescribe low-dose suppressive antibiotic therapy for all newborns after bladder closure. This is continued until the vesicoureteral reflux is corrected or it resolves spontaneously.

Postoperative factors that appear to have a direct impact on the success of initial closure include:

- Postoperative immobilization
- Use of postoperative antibiotics
- Ureteral stenting catheters
- Adequate postoperative pain management
- Avoidance of abdominal distention
- Adequate nutritional support
- Secure fixation of urinary drainage catheters.^{6,7}

COMPLETE PRIMARY EXSTROPHY REPAIR SURGICAL TECHNIQUE

Initiation of repair

To provide maximal exposure, we use an extremity drape after sterily preparing the child from the

xiphoid to the toes. Following this, we place 3.5 Fr umbilical artery catheters into both ureters and suture them in place with 5.0 chromic suture. We then outline the planned lines of dissection using semipermanent marking (Figures 29.3 and 29.4). Initial dissection begins superiorly at the level of the umbilicus. After a plane has been established between the bladder and the peritoneal cavity, the dissection proceeds inferiorly to separate the bladder plate from the adjacent skin and fascia. We use fine-tip electrocautery (Colorado® tip) during this dissection to minimize bleeding. The umbilical cord usually needs to be mobilized on its vessels in a cephalad direction such that the resulting umbilicus will be in a more orthotopic position at a level above the iliac crests. The relocated umbilicus will also be the cutaneous site for the suprapubic tube. It is important to remember that dissection for this repair technique should be extraperitoneal.

Initiation of complete penile disassembly

At the beginning of this repair, we place traction sutures transversely into each hemiglans of the penis. The sutures will rotate to a parallel vertical orientation as the corporal bodies rotate medially following dissection of the corporal bodies and the urethral wedge (urethral plate plus underlying corpora spongiosa) from each other.

It is easiest to begin the penile dissection along the subcoronal ventral aspect of the penis (Figure 29.5). This should precede dissection of the urethral wedge from the corporal bodies because it is easier to identify Buck's fascia ventrally. The initial plane of dissection is found just above Buck's fascia. Buck's fascia stops at the corpora spongiosum during the dissection; as the dissection progresses medially, the plane shifts subtly from above Buck's fascia to just above the tunica albuginea. The application of methylene blue or brilliant green helps differentiate urothelium from squamous epithelium and can aid in identifying the plane of dissection. This is critical to avoid narrowing the urethra which will be tubularized later. Injection of the surrounding tissues with 0.25% lidocaine and 1 : 200 000 U/ml epinephrine improves hemostasis, and this assists dissection. The margins of the dorsal urethra are usually obvious. Urethral wedge dissection is carried proximally to the bladder neck. Careful lateral dissection of the penile shaft skin and dartos fascia from the corporal bodies is important to avoid damaging the neurovascular bundles located laterally on the corpora of the epispadic penis. Under the urethral wedge, the dissection plane is carried medially on the tunica albuginea of the corpora cavernosa.



Figure 29.3 Ventral view of outlines of planes of dissection.

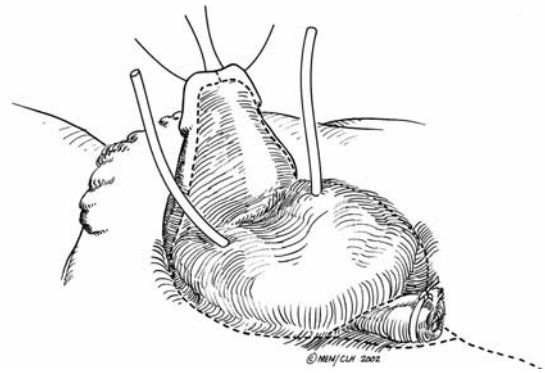


Figure 29.4 Dorsal view of outlines of planes of dissection.

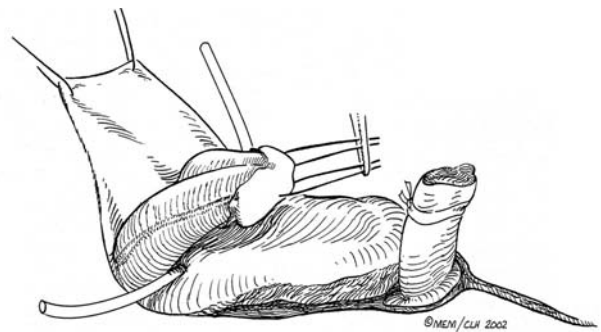


Figure 29.5 Subcoronal initiation of dissection. This is typically the easiest plane in which to initiate dissection.

Complete penile disassembly

Complete penile disassembly (CPD) is done primarily to provide exposure for dissection of the intersymphyseal band and to allow optimal deep pelvic dissection. The penis is surgically disassembled into three components, the right and left corporal bodies with their respective hemiglans and the urethral wedge (urethra with underlying corpora spongiosa).⁸ We find it easiest to proceed

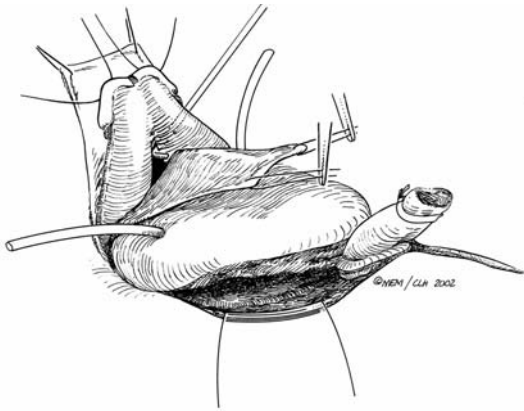


Figure 29.6 Corpal dissection proximal and ventral. The initiation of corpal separation is easiest to establish proximally.

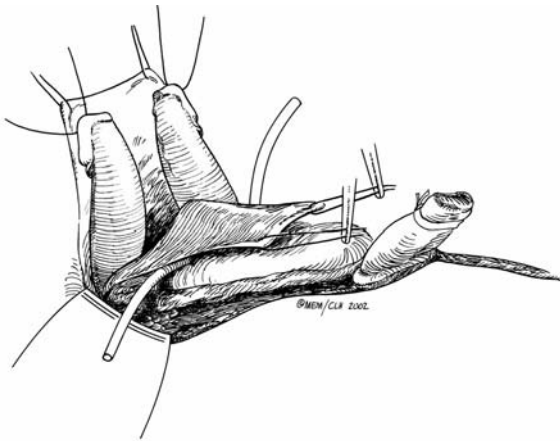


Figure 29.7 Separation of corpal bodies and urethra.

with corpal disassembly proximally and ventrally (on the underside of the corpora cavernosa) (Figure 29.6). After a plane is established between the urethral wedge and the corpal bodies, this dissection can be advanced distally to separate the three components from each other (Figure 29.7). It is possible to separate the corpora bodies from each other since they exist on separate blood supplies. It is important to keep the underlying corpora spongiosum with the urethral plate since the blood supply to the urethral plate is based on this corpal tissue which should appear wedge shaped after its dissection from the adjacent corpora cavernosa. The urethral/corpal spongiosal component will later be tubularized and placed ventral to the corpal bodies. We discourage the use of para-exstrophy skin flaps for urethral lengthening because this maneuver may devascularize the distal urethra. However, in some cases, a male patient will be left with a hypospadias that will require later surgical reconstruction (short distal urethra).

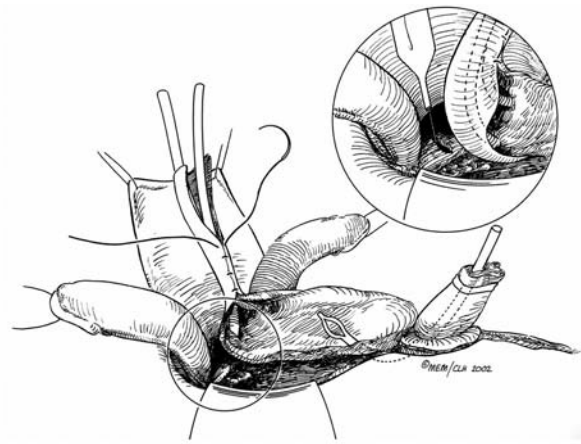


Figure 29.8 Deep pelvic dissection. Division of the intersymphyseal band is critical to allowing placement of the bladder in the pelvis.

Deep pelvic dissection

Proximal dissection of the urethral wedge from the corpal cavernosa bodies increases exposure of the pelvis and the intersymphyseal band or ligament. The dissection should follow planes along the medial aspects of the corpal bodies (Figure 29.8). Deep incision of the intersymphyseal ligaments posterior and lateral to each side of the urethral wedge is critical to allow the bladder to achieve a posterior tension-free position in the pelvis (Figure 29.9). This dissection should be continued until the pelvic floor musculature becomes visible (i.e. the intersymphyseal ligament is completely incised). Failure to adequately dissect the bladder and urethral wedge from surrounding structures will create anterior tension along the urethral plate and prevent posterior movement of the bladder in the pelvis.

Reconstruction

After the bladder and urethral wedge are dissected from the surrounding tissues, reconstruction of the bladder, bladder neck, and urethra is anatomic. The importance of recognizing the proper location of the bladder neck is key (in boys proximal to the verumontanum and in girls just distal to the trigone). Prior to reapproximating the bladder, a suprapubic tube is placed and brought out through the umbilicus. We then tubularize the urethra using a two-layer running closure with monofilament and Vicryl®. Following this, we perform a primary closure of the bladder using a three-layer closure with absorbable suture (i.e. Monocryl® and Vicryl®) suture (Figure 29.10). Pubic reapproximation moves the bladder and tubularized

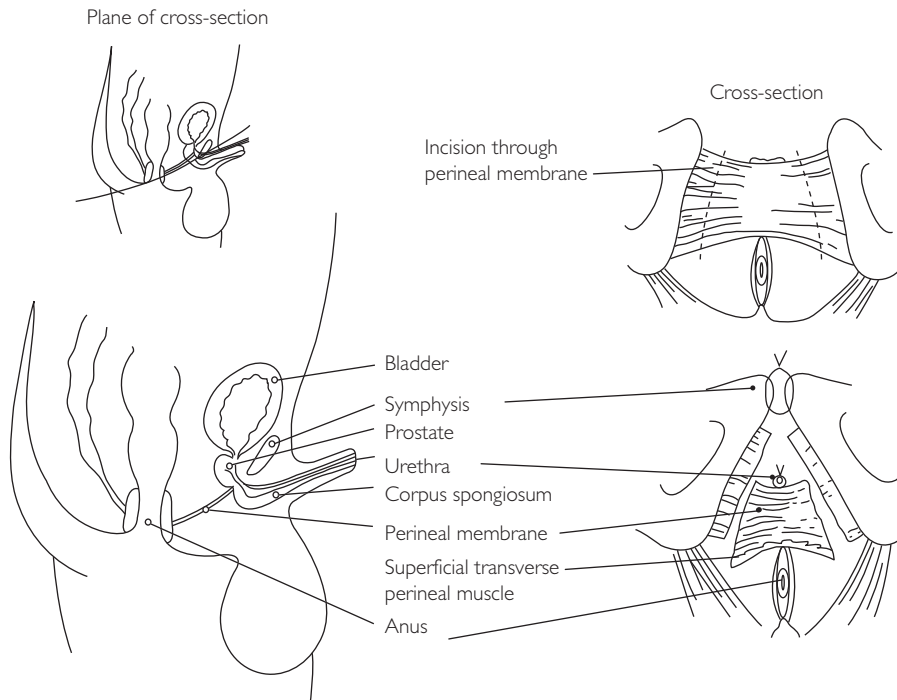


Figure 29.9 Posterior tension free-position (cross-section).

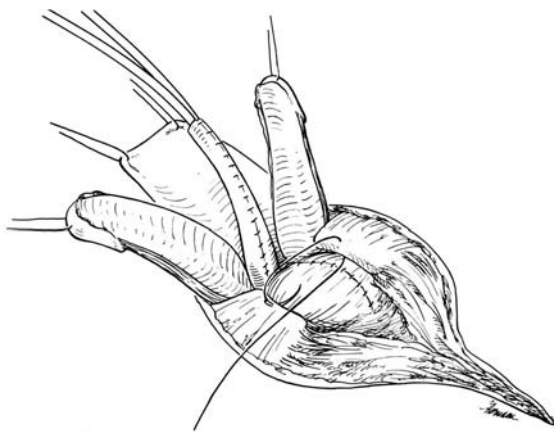


Figure 29.10 Bladder closure. The bladder and urethra are closed in several layers. Urinary drainage is established through ureteral catheters and a suprapubic tube.

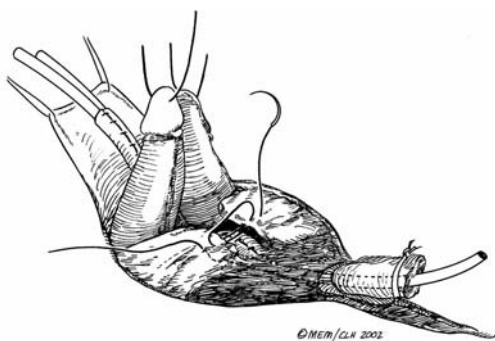


Figure 29.11 Pubic symphysis closure. The pubic symphysis is reapproximated using absorbable suture. Osteotomies are used when needed to allow a low-tension reapproximation.

urethra posteriorly where the urethra is ventral to the corpora in an anatomically normal position.

We reapproximate the pubic symphysis using 0.0 and 1.0 polydioxanone (PDS) interrupted figure-of-eight sutures. Knots are left anterior to prevent suture erosion into the bladder neck (Figure 29.11). Rectus fascia is reapproximated using interrupted 2.0 PDS sutures. The umbilicus is secured in its new location using interrupted 3.0 PDS sutures and 4.0 chromic sutures to reapproximate skin. Penile shaft skin may be reconfigured using either a primary dorsal closure or reversed Byars flaps if needed to provide dorsal skin coverage. Alternative methods of penile shaft skin coverage include mobilization and rotation of skin flaps between the scrotum and base of the penis as described by Kulkarni et al or ventral-to-dorsal rotation of ventral penile shaft skin on a vascular island of dartos.⁹ Use of these techniques is individualized to the situation at hand. Skin covering the abdominal wall is reapproximated using a two-layer running closure of absorbable monofilament suture.

The corporal bodies will rotate medially with the pubic and fascial closure. This rotation will assist in correcting the dorsal deflection and can be readily appreciated by observing the vertical lie of the previously horizontally placed glans traction sutures. Occasionally, significant discrepancies in the dorsal and ventral lengths of the corpora will require dermal graft insertion. However, this is rarely needed in the newborn closure. The corpora are reapproximated with fine interrupted suture along their dorsal aspect

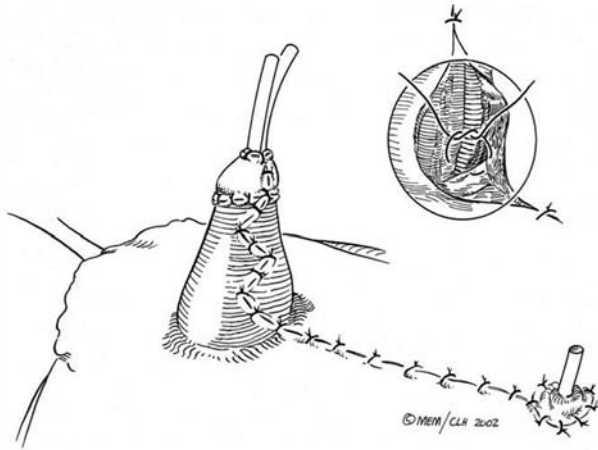


Figure 29.12 Skin coverage. Z-plasties are used to provide adequate dorsal skin coverage.

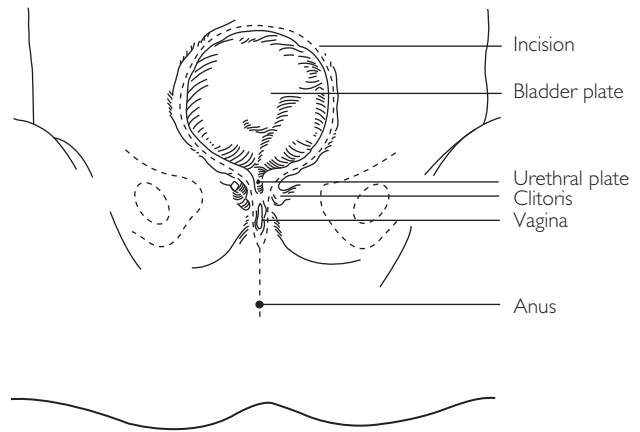


Figure 29.15 Y-V plasty. Line drawing indicating the initial lines of dissection for a female exstrophy repair.

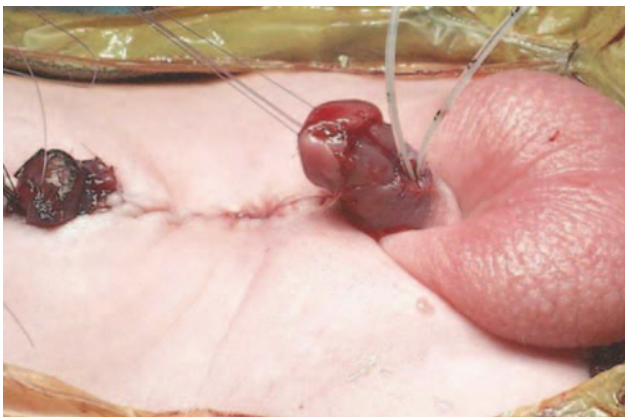


Figure 29.13 Hypospadias can occur as a consequence of the placement of the urethra and bladder deep in the pelvis.

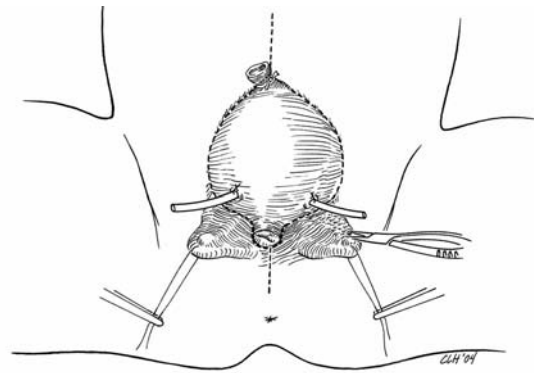


Figure 29.16 Initial lines of dissection for female repair.



Figure 29.14 Newborn girl with classic bladder exstrophy.

with care taken to avoid the more dorsally located neurovascular bundles.

The urethra can then be brought up to each hemiglans ventrally to create an orthotopic meatus (Figure 29.12). The glans is reconfigured using interrupted mattress sutures of polydioxanone suture followed by horizontal mattress sutures of 7.0 monofilament suture (i.e. Maxxon®) to reapproximate the glans epithelium. The neourethra is matured with 7.0 braided polyglactin suture (i.e. Vicryl). Sculpting the glans including resection of epithelial tissue along the medial aspect of the hemiglans will create a conical and smooth appearing glans. In roughly half of our cases, the urethra lacks enough length to reach the glans. In this situation the urethra may be matured along the ventral aspect of the penis to create a hypospadias (Figure 29.13). This can be corrected at a later date as a second stage procedure. We often leave redundant shaft skin ventrally in these patients to assist in later penile reconstructive procedures.

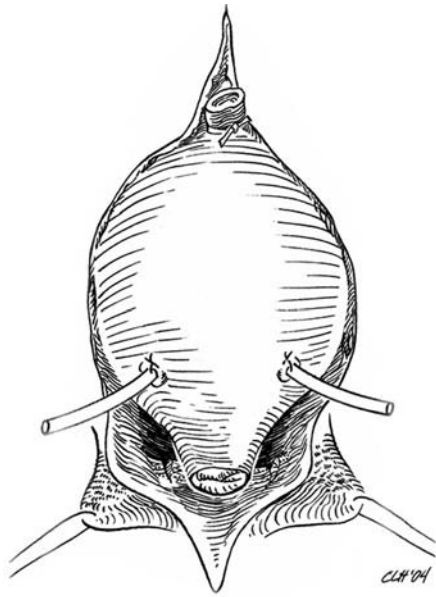


Figure 29.17 Lateral dissection planes in female repair. It is important to recognize that the walls of the vaginal vault may be more lateral than initially appreciated during dissection.

FEMALE COMPLETE PRIMARY EXSTROPHY REPAIR TECHNIQUE

The principles of repair are analogous for boys and girls. We prefer to perform the reconstructive surgery for girls during the neonatal period for the same reasons that we do in boys (Figures 29.14 and 29.15).

Initial dissection

The lines of initial dissection are depicted in Figure 29.16. The bladder neck typically has dysplastic tissue adjacent to it. We tailor the bladder neck dissection in an effort to clearly define the bladder neck in the hope that this will improve later bladder neck function and continence. As in boys, the bladder neck, urethra, and vagina are mobilized as a unit. We perform this dissection with tungsten-tip electrocautery (Colorado tip) to minimize tissue damage while achieving hemostasis. The appropriate plane of dissection is found anteriorly along the medial aspect of the bifid clitoris and proceeds posteriorly along the lateral aspect of the vaginal vault (Figure 29.17). The vagina is mobilized with the urethral plate and bladder neck. We discourage developing a plane of dissection between the urethra/bladder neck and anterior vaginal wall as this may compromise the blood supply to the urethra.

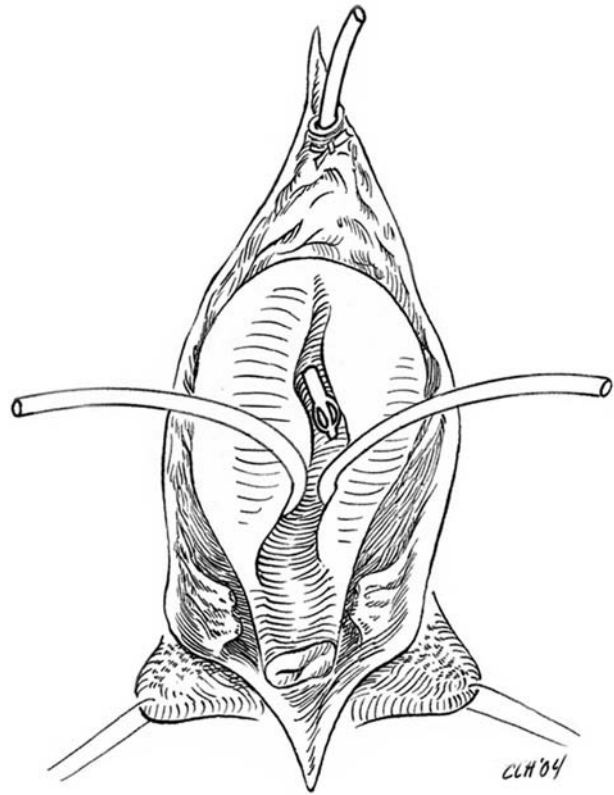


Figure 29.18 Urethral tubularization. The urethra should not be separated from the anterior vagina as this may compromise the blood supply to the urethra.

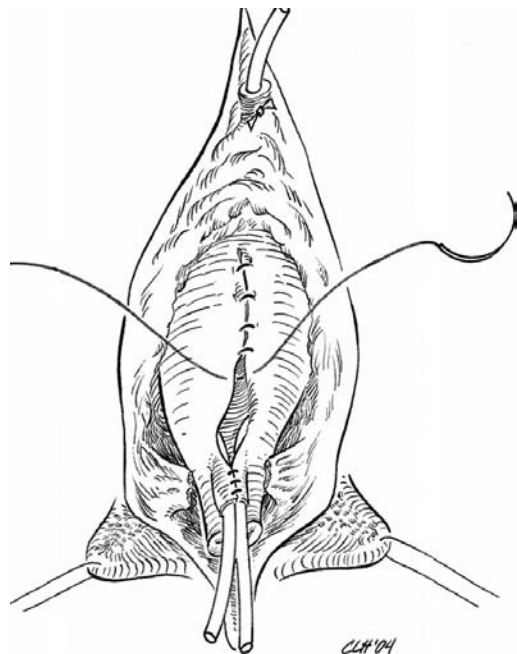


Figure 29.19 The bladder and urethra are closed in multiple layers. The suprapubic tube is brought out superiorly.

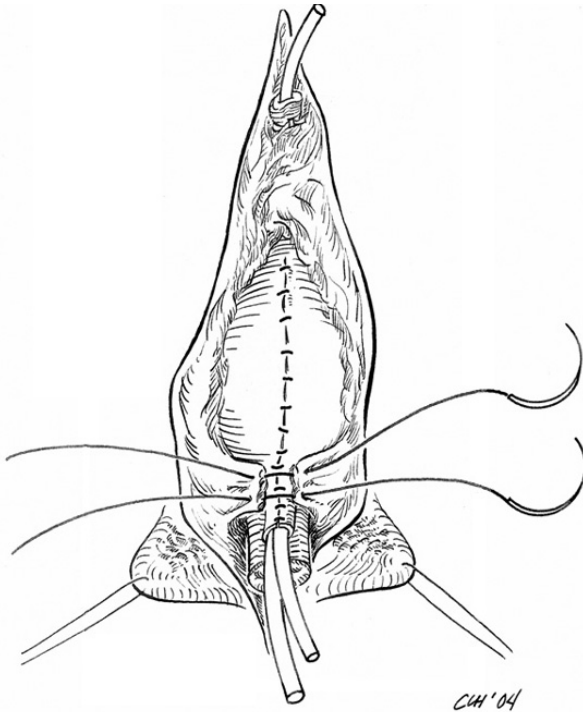


Figure 29.20 Pelvic positioning in the female exstrophy repair. The pubic symphyses are reapproximated using absorbable suture.

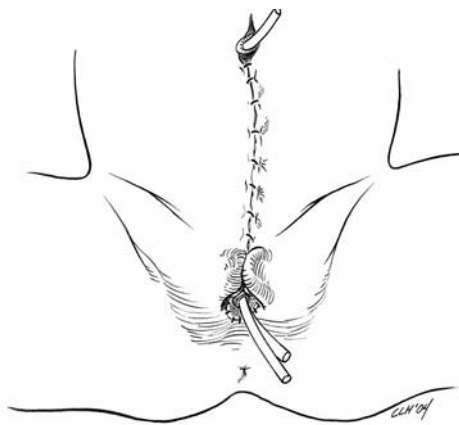


Figure 29.21 Introital repair.

Pelvic dissection

As tissue dissection proceeds posterolaterally, the intersymphyseal band will be encountered. This condensation of tissue should be deeply incised to allow the vagina, urethra, and bladder neck to move posteriorly in a tension-free fashion. The posterior limit of the dissection is reached when the pelvic floor musculature is exposed. The proximal urethra can be lengthened to some degree with parallel incisions in the bladder plate to the trigone during bladder neck tailoring.

Reconstruction

Following deep dissection, the vagina and urethra are advanced posteriorly in the perineum. The urethra is then tubularized using a two-layer closure of absorbable suture (Figure 29.18). After urethral tubularization, we routinely place a suprapubic tube to provide postoperative urine drainage (Figure 29.19). The bladder, bladder neck, and urethra should be positioned deeply in the pelvis and traverse the pelvic diaphragm. The pubic symphysis is then reapproximated using a 1.0 and 0.0 PDS figure-of-eight suture with the knots left anteriorly to prevent their erosion into the bladder neck (Figure 29.20). As in the repair in the boy, osteotomies are necessary when a wide pubic diastasis or inflexible bony pelvis prevents a low-tension reapproximation of the pubic symphysis. We favor anterior iliac osteotomies in these situations.

Following pubic reapproximation, the rectus fascia is closed in the midline using 2.0 PDS suture in an interrupted fashion. We mature the neourethra with 5.0 Vicryl sutures and reapproximate the already denuded bifid clitoris medially so that they fuse together with 7.0 Maxxon suture. This must be done carefully to avoid damaging the clitoral bodies and may be deferred until the child is larger. The labia majora are advanced posteriorly to the perineum at this time to improve cosmesis of the external genitalia (Figure 29.21). A Z-plasty skin closure can be employed as well to decrease tension especially inferiorly.

COMPLETE PRIMARY EXSTROPHY REPAIR MODIFICATIONS

Several authors have reported modifications of this technique. Caione et al described the use of an electrical muscle stimulator during deep pelvic dissection to preserve and reconfigure the periurethral muscle complex. Long-term results of this patient series have not yet been reported; preliminary results are promising.¹⁰

Others have described a modification of the penile disassembly technique preserving the connection between the distal urethral wedge and the corporal bodies to decrease the incidence of hypospadias.¹¹

In an effort to decrease urethrocuteaneous fistula formation we have placed folded one-ply submucosal intestinal substance or Alloderm® between the bladder and rectus fascia but results using this modification are too preliminary to assess.

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30 Enterocystoplasty and catheterizable stomas

Anthony J Casale

ENTEROCYSTOPLASTY

Introduction

Enterocystoplasty originated in 1912 when Lemoine reported the first use of sigmoid colon to augment the bladder. Couvelaire¹ introduced the cecum as an alternative segment for bladder augmentation in 1950 and this contribution was followed by Goodwin et al^{2,3} in 1959 who described the use of ileum for the same purpose. Enthusiasm for enterocystoplasty heightened in the 1980s when the long-term risks of ureterosigmoidostomy and urinary diversion became evident.^{4,5,6,7} Advantages of retaining part or the entire native bladder together with the ureterovesical junction include lower risk of stenosis, infection, and cancer.

Today, enterocystoplasty is the most common and most practical method of augmenting the poorly functioning bladder in cases of neuropathic bladder due to trauma or congenital spinal disorders and in cases of deficient detrusor secondary to exstrophy, cloaca, or trauma.

Indications

Augmentation cystoplasty is performed when the bladder volume or pressure is inadequate to protect the upper urinary tracts or to provide for continence. Signs and symptoms of severe bladder dysfunction vary considerably; patients may be asymptomatic or suffer from symptoms including renal insufficiency, recurrent symptomatic urinary infections, abdominal pain, and all levels of incontinence. Surgeons should turn to augmentation only after maximal medical therapy fails to lower pressures and increase volume. Medical management should include extended trials of anticholinergic medications and intermittent catheterization. Hostile bladders as defined by small capacity, overactive detrusor contractility, and low compliance may result from primarily neurologic or anatomic conditions in the US, but can result from infectious causes in other parts of the world.

Neuropathic bladder is by far the largest group of patients undergoing augmentation. Congenital spinal conditions such as myelomeningocele or sacral agenesis make up the large majority of neuropathic bladder patients in children. Spinal cord trauma does occur in children but is

less prevalent than in adults. Bladder capacity is decreased because of chronic hypercontractility of the detrusor which leading to thickening and fibrosis. The bladder lacks the elasticity and compliance to accept urine without resultant pathologically high pressures.

Anatomic conditions which lead to augmentation are primary or secondary problems with the detrusor muscle. Exstrophy, cloaca, and posterior urethral valves can produce small-capacity high-pressure poor-compliance bladders. Secondary bladder damage from radiation therapy and some forms of inflammatory cystitis can produce small scarred bladders with poor compliance.

Patient selection and preparation

The single most important decision for the surgeon considering enterocystoplasty is patient selection. The criteria for selection are two fold and based on bladder performance and patient behaviour. Bladder performance criteria are simple. Patient compliance decisions are difficult and are most critical. It is important to identify the goals of therapy which may include continence, increased urine storage time, improved drainage of the upper urinary tracts, and a decrease in symptomatic urinary tract infections.

The bladder must be evaluated both radiographically with contrast studies and functionally with urodynamic studies. Typically, the radiographic cystogram will demonstrate bladder capacity, shape, bladder wall thickness, the presence or absence of reflux, and the appearance of the bladder neck with bladder filling. Often diverticuli of the bladder and trabeculation of the detrusor are present.

Urodynamics will document functional bladder capacity and define storage and filling pressures. Leak point pressure, the pressure when urine passively leaks from the bladder is important not only in attaining continence but also in keeping storage pressures safe for the upper tracts. Uninhibited contractions with high pressures produce episodic incontinence and may producing damage upper tracts reflux or inefficient drainage or transmitting pressure to the upper tracts. Electromyograms will usually show little if any coordination of the sphincter and detrusor. The sphincter in patients who typically require enterocystoplasty is usually fixed and non-functional.

The bladder appearance and performance of most patients who undergo enterocystoplasty reveals a thick-walled small-capacity poorly compliant bladder with little contractility.

More practical information regarding bladder performance is obtained with a catheterization diary. For instance, a bladder which has good compliance and pressures at moderate volumes may be better managed with more frequent catheterization instead of surgery. It is important to compare data from urodynamics with those from catheterization diaries to determine optimal management. The care of children is further complicated by the projected growth of the child and the projected level of function of the bladder. Frequently, we find the child is growing and increasing urine output while the bladder is losing capacity or its growth cannot keep pace with future demand for urinary storage.

Patient selection is more difficult than deciding on bladder needs and depends on the ability of the surgeon to judge if the patient and family are committed to the necessary care and routine required by enterocystoplasty. A long history of compliance with catheterization and medication is the best indicator of success. Since most families and patients have little problem performing their care from a technical standpoint the question is motivation and the ability to consistently carry out the care plan on schedule. It is extremely helpful if both parent and patient are in agreement with the desire for this form of bladder management. Other patient issues must be considered such as renal function, ability of the patient to perform catheterization, general state of health, and life expectancy. Augmentation cystoplasty is often performed to improve quality of life and these benefits must be weighed against the risks and costs to the patient and family.

Choice of bowel segment

Enterocystoplasty can be performed with a number of bowel segments including ileum, cecum, and colon. Either the transverse or sigmoid colon may be used. The choice of any bowel segment must rely on the mobility of the segment and the length of the mesentery. The segment must reach the bladder easily and this should be measured prior to harvesting any bowel for augmentation.

Factors to be considered in choosing a bowel segment include availability, other conditions and diseases of the bowel, and the amount of bowel needed for reconstructive procedures.

Cecocystoplasty

The cecum has been used for augmentation since the 1950s when Couvelaire described the procedure. The

cecum was appealing because it could be harvested as a large caliber tube or cap and simply rotated for placement on top of the bladder. The cecum is the thinnest portion of the colon, has a large diameter, and is usually quite mobile. Some cecocystoplasties have demonstrated increased pressures due to mass contractions of the cecum and to resolve this problem the cecum should be surgically reconfigured. Cecocystoplasty is performed by harvesting the cecum with approximately 12–15 cm of ascending colon based on the blood supply of the ileocolic artery. The cecum should then be opened along its antimesenteric border and either sewn on the open bladder as a flat patch or combined with a segment of ileum in order to prevent a cohesive contracting unit and to maximize the bladder volume.

Unfortunately the ileocecal valve must be taken with the cecum. In the past the terminal ileum was taken en bloc and used as a catheterizable urinary stoma. The Indiana Pouch continent diversion based on the work of Gilcrest utilizes the ileocecal segment. A distinct disadvantage of using the cecum in patients with neuropathic bowel such as myelomeningocele is that removing the ileocecal valve often leads to diarrhea which is difficult to control. For this reason many surgeons have avoided using this segment when possible.

Potential advantages of cecocystoplasty include the presence of the tenia coli which are convenient sites for anastomosis of ureters or catheterizable channels to the augmented segment. In addition, the appendix, if present, has the potential to be used as a catheterizable channel, although it would need surgical plication at the base to make it continent. The cecum is seldom used today for simple augmentation.

Colocystoplasty

Colocystoplasty using sigmoid colon is still some surgeons preferred method. The sigmoid is often large and redundant in patients with neuropathic bladder and bowel due to chronic constipation and its close proximity makes this segment useful. On the other hand, some patients have a thick-walled narrow-caliber sigmoid colon requiring a long segment for an adequate augmentation. Optimally a 15–20 cm segment of the midsigmoid is chosen based on mesenteric blood vessels. Blood supply is from the inferior mesenteric artery (Figure 30.1).

Advantages of sigmoid colon cystoplasty include location of both the segment and the muscular bowel wall. This procedure may be performed through a transverse lower abdominal incision which is more cosmetic and less prone to dehiscence than a midline incision. Since the bowel anastomosis necessary after



Figure 30.1 Sigmoid cystoplasty. (A) A sigmoid segment of adequate length is removed from the gastrointestinal tract and a colocolostomy is performed. (B) and (C) The colon is opened along the antimesenteric border and anastomosed to the bivalved bladder after being reconfigured as a flap, S, or U shaped augment.

harvesting of sigmoid is so low in the alimentary tract it lessens the need for a nasogastric tube after surgery. The thick colon wall and presence of tenia coli allow easier antirefluxing anastomosis of either ureter or catheterizable channels into the augmented segment.

There are some disadvantages of colon. Some patients develop diarrhea after the sigmoid is harvested. Another significant disadvantage is the presence of strong unit contractions inherent in this segment. If the colon is not reconfigured these contractions will lead to urinary incontinence or upper tract deterioration due to increased intravesical pressures. The colon must be detubularized along its antimesenteric border and it may be reconfigured as a 'U' or 'S' shaped flap or sewn on as a diamond shaped flat flap. Colon produces more mucus than other bowel segments and this may increase the risk of urinary infections and stone formation. Some authors have demonstrated an increased incidence of perforation in sigmoid cystoplasty.⁸

Ileocystoplasty

Ileocystoplasty has clearly emerged as the bowel segment of choice for enterocystoplasty. It is plentiful, produces less mucus than colon, and has a long and mobile blood supply. A segment of ileum is selected at least 20 cm proximal to the ileocecal valve to preserve vitamin B12 and bile salt metabolism. The length of the small bowel segment depends on the circumference of the ileum and the size of the bladder to be augmented. Typically a 15–25 cm segment is harvested. Selection criteria for the ileal segment include length of the blood supply, prior bowel anastomosis, local width of the ileum, and the presence and density of adhesions. Before any incision is made in the bowel or mesentery the proposed segment must be placed adjacent to the bladder in the approximate position where it would lie as an augmentation to ensure that the mesentery is long enough. The ileum always needs

to be detubularized along the antimesenteric border and reconfigured as a flap. The length of the ileal mesentery makes it necessary to tack the augmented segment and mesentery to adjacent structures in order to try and avoid internal hernias and volvulus.

The ileum is measured and marked with stay sutures in pairs which mark each edge of the divided bowel. The mesentery adjacent to each proposed bowel incision is carefully divided for several centimeters to preserve a good arterial supply to the harvested segment. This mesenteric incision can be done with clamps and ties or with a bipolar bovie to prevent mesenteric bleeding. After the site is isolated from the rest of the abdomen with surgical sponges soaked with antibiotic solution, the bowel can then be divided with either bowel clamps or staples to avoid spilling enteric contents into the wound. The remaining bowel can then be placed back into continuity using either a hand sewn or stapled anastomosis and the opening in the mesentery can be closed with sutures.

Once the ileum has been isolated, it is opened at each end and carefully irrigated with antibiotic solution to wash out any remaining bowel contents. The bowel is then opened along its antimesenteric border using a hemostat to pull the bowel away from the mesentery and cautery to incise the bowel wall and prevent bleeding. After the bowel is opened as a long flap the surgeon can then plan reconfiguration by seeing which part of the ileum will reach the points farthest from the root of the mesentery, namely the lowest points of the bladder incision above the bladder neck and the trigone. The ileum can then be sewn into a 'U', 'S', or 'W' shaped flap with absorbable sutures and positioned on the bladder (Figure 30.2). The flap is sewn onto the bivalved bladder by starting in the posterior midline and running suture around each side toward the anterior midline. After the bowel is in place any gaps which could cause internal hernia should be closed with permanent sutures and the abdomen irrigated.

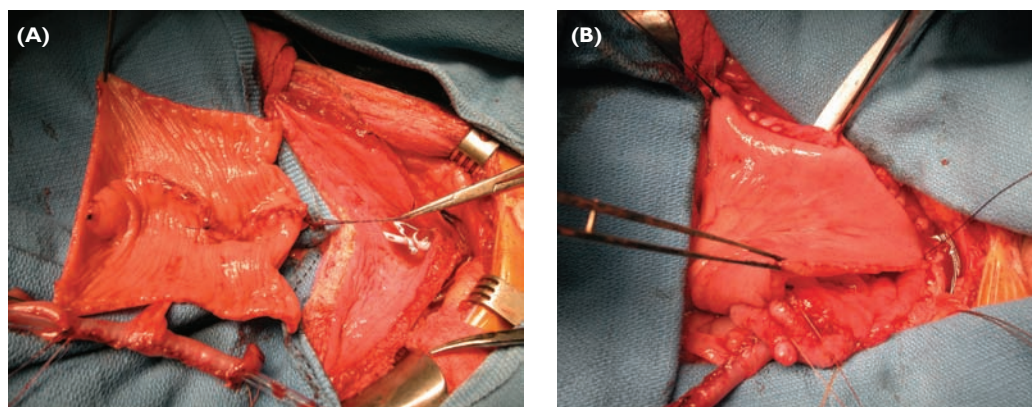


Figure 30.2 (A) Ileal patch reconfigured as a U shaped flap aligned with the bladder at right. (Monti channel created from ileum is just below ileal patch.) (B) The ileal patch is being sewn to the bladder.

Surgical management of the bladder

Current management of the bladder that is to be augmented encourages preserving the entire native bladder despite its appearance and poor urodynamic properties. The bladder wall itself can be rehabilitated when intravesical pressures are decreased after augmentation. The bladder should be opened in either the midline or slightly asymmetrically if one side of the bladder is to be used as a flap to allow anastomosis of a catheterizable channel. The bladder is bivalved from just above the bladder neck anteriorly to just above the trigone posteriorly. This can be performed with cautery since the bladder bleeds vigorously even when fibrotic. Stay sutures are helpful when placed along the sides of the incised bladder in making the incision and in planning and performing the augmentation. Adequate bladder drainage is imperative and should include a large caliber suprapubic tube which is placed through the native bladder instead of the augmented bowel. The drainage tubes should be carefully anchored within the bladder with absorbable sutures and at the exit site of the bladder wall. A second catheter is necessary through either the urethra or a catheterizable urinary channel.

The anastomosis of the bowel segment to the bladder is performed using running absorbable sutures starting in the posterior midline with two sutures and working around each side to the anterior midline. We use three separate sutures on each side of the bladder and irrigate the bladder during the procedure to wash out mucus and blood. At the close of the augmentation the bladder is filled with irrigation and any significant leaks are repaired with interrupted sutures. We do not attempt to make the anastomosis absolutely watertight to prevent harming the blood supply at the anastomosis.

Postoperative care

Management of the patient after the surgery is critical. Broad spectrum antibiotic coverage is continued for at

least 2 days. A nasogastric tube is left in place until the bowel begins to function. The bladder must be drained with two separate catheters to ensure that one does not become occluded in the postoperative period leading to leakage of urine into the abdominal cavity. Usually one catheter is left in the catheterizable channel and one is a suprapubic tube of large caliber.

Immediately after surgery a program to irrigate the catheters is instituted with normal saline to wash out mucus and keep the tubes patent; the catheters are irrigated every 4 hours and more often if necessary. At the time of discharge irrigation is performed twice daily. This is continued at home and, after both catheters are removed, the family is instructed to irrigate the bladder with 30 ml of normal saline nightly to prevent mucus accumulation.

The goal is to keep the bladder decompressed for at least 3 weeks after surgery before removing the first tube. Typically, the channel catheter is removed first and the suprapubic tube is capped and only removed after the family can demonstrate they can successfully empty the bladder by catheterizing the channel for a week. Catheterization is started every 3 hours and the suprapubic catheter is open to drainage during the night to make sure that the augmented bladder is allowed to adapt to filling gradually. After 4 days the family is instructed to plug the suprapubic tube and catheterize every 3 hours around the clock. If this regimen is working well we remove the suprapubic tube after 1 week and start a 4 hour schedule. After a month we allow the child to go 6 hours over night and continue catheterizing every 4 hours during the day.

We do not perform postoperative cystograms or urodynamics unless there is a clinical problem or an abnormal upper tract ultrasound. We see them frequently during the first few months after surgery and monitor the upper tracts with ultrasound. Every 6 months, we follow the children with a plain film of the abdomen to look for calculi and a renal ultrasound. After 1 year, we see them yearly for life with the same studies. Large adolescents or

adults usually have a yearly non-contrast computed tomography (CT) instead of plain films and ultrasound.

Results of enterocystoplasty

Results of enterocystoplasty are usually measured by how well the surgery addresses the indications for surgery, namely improved bladder performance. Increase in capacity, decreasing bladder contractility, improving compliance and decreasing bladder storage pressures are improved in all forms of enterocystoplasty. Control of symptomatic urinary tract infection, decompression and maintenance of upper urinary tract function, and improved continence are all reliable results of enterocystoplasty.

Both small and large bowel enterocystoplasties appear to improve bladder capacity and compliance. In a study of 30 children augmented with sigmoid, ileum, and ileocecum postoperative urodynamics revealed similar improvements in capacity and compliance.¹⁰ When reconfigured properly both are acceptable. There was a higher incidence of failure with colon in the past due to its increased ability for mass contractions and inadequate reconfiguration.¹¹ So while volume and compliance are relatively independent of bowel segment, colon does have a tendency toward more active contractions which can cause intermittent high pressures in the augmented bladder.

Augmentation has been successful in decreasing symptomatic urinary infections, resolving vesicoureteral reflux in some cases, providing improved continence, and improving upper tract drainage. All of these symptomatic improvements are as a result of better bladder performance with lower storage pressures and increased capacity.

Complications of enterocystoplasty

Complications of enterocystoplasty include stones, chronic bacteriuria, electrolyte abnormalities, bladder rupture, and cancer. While the benefits of enterocystoplasty cannot be denied, neither can the complications. Metcalfe et al found, in a review of 500 children who underwent enterocystoplasty and were followed for a mean of 13.3 years, that 34% suffered complications that required surgery with 254 additional surgeries being required in 169 patients.¹² By performing an enterocystoplasty the surgeon places serious responsibility on the patient and their family to catheterize the bladder on time, irrigate the bladder, and to have life-long medical surveillance.

Bowel is an absorptive organ and when the bowel is used for cystoplasty the potential exists for metabolic changes to develop due to long periods of prolonged exposure to urine introduces the risk of acquired metabolic disturbances. In patients with normal renal function these changes do not affect serum electrolytes.^{13,14} Patients with renal insufficiency, however,

are at risk of developing profound metabolic hyperchloremic acidosis due to ammonium reabsorption.¹⁵ Demineralization and inhibited bone growth are potential risks of chronic acidosis. Hall et al found that there was an increase in urinary acid load with wasting of bone buffers even without frank acidosis.¹⁶ Wasting of bone buffers can result in bone demineralization and possibly cause impairment of bone growth and bone density.^{17,18,19} At this point there are conflicting data available about growth impairment in patients with enterocystoplasty but the potential for interference in bone growth should be considered and explained to patients prior to surgery.

Both small and large bowel produce mucus which can contribute to chronic bacteriuria and stone formation.^{20,21} Mucus should be cleared with daily irrigation and this practice may decrease the risk of infection and calculi.^{8,22} Mucus production may decrease with time in some patients and often varies on a daily basis. Stones occur in around 15% of patients following enterocystoplasty in the largest series in the literature of 500 children.¹¹ Mean time to stone formation was 5.6 years and 37% had stone recurrence during the time followed. The majority of bladder stones after enterocystoplasty are struvite indicating that chronic bacteriuria is an important component in stone formation. All stone forming bacteriuria should be cleared from the urine to help prevent stone production.

Bacteriuria is common after enterocystoplasty but it is dependent on the practice of clean intermittent catheterization (CIC).²³ Patients who can void with bowel neobladders can maintain sterile urine whereas patients on CIC will often have bacteriuria even in the absence of enterocystoplasty. Even with antibiotic suppression and bladder irrigation urine cultures are usually positive in augmented patients who perform CIC.^{24,25} Symptomatic cystitis occurred in 23% of patients after ileocystoplasty and 17% after colocolocystoplasty, and febrile infections in 13% in a review of 234 children after augmentation.²⁵ Symptomatic infection is usually not a significant problem if the patient catheterized regularly to empty the bladder. An increase in the frequency of infections often indicates a failure in patient compliance to perform CIC. Asymptomatic bacteriuria with non-stone forming organisms does not require treatment in patients who perform CIC. Antibiotic prophylaxis usually does not influence the risk of symptomatic infection and results in bacterial resistance.

The risk of delayed spontaneous bladder perforation is the most threatening complication of enterocystoplasty since it is not a rare event and can cause severe illness or death.²⁷ Metcalfe et al found an 8.6% perforation rate in 500 patients with 53 perforations occurring in 43 patients.¹¹ Patients with neuropathic bladder usually have decreased abdominal and pelvic sensation so that a perforation may not cause significant pain for

some time. Delayed diagnosis of the perforation can lead to septic shock and in rare cases death. A high index of suspicion for perforation should be applied to any patient who has undergone augmentation cystoplasty who presents with abdominal distention, abdominal or shoulder pain, low urine output, fever, nausea or vomiting. CT cystography is the diagnostic imaging study of choice and the threshold for ordering this study on any ill patient with a history of this surgery should be low.

The etiology of perforation is unclear but may involve catheterization trauma in some patients.²⁸ More often the etiology is due to chronic over distention as a result of infrequent catheterization.²⁹ It is postulated that over distention leads to ischemia and bowel segments adjacent to perforations have demonstrated necrosis, vascular congestion, hemorrhage, and hemosiderin consistent with chronic ischemia.³⁰ Perforations occur within the bowel segment itself most commonly and have occurred within all bowel segments. Different studies have found a higher incidence of perforation related to a specific bowel type but these are inconsistent. Indiana University found a higher incidence of perforation within sigmoid augmentation, while Boston Children's Hospital found a higher incidence with ileum.^{11,31} The etiology and risk factors for spontaneous bladder perforation appear multifactorial and have yet to be clearly defined. The risk must be explained prior to surgery and recognized by all physicians who care for these children after surgery.

The first report of tumor formation in augmented bladders was by Filmer and Spencer in 1990.³² These authors found 14 cases of adenocarcinoma in augmented bladders, nine after ileocystoplasty and five after colcystoplasty. Some later reports have reported transitional cell carcinoma with fatal results.^{33,34} In the tumors that occur after ureterosigmoidostomy where bowel and bowel mucosa are found in association with urine, the latency period averaged 26 years.³⁵ While the pathologic conditions are not identical with fecal material appearing to play a significant role in the high risk of malignancy in ureterosigmoidostomy, it is clear that the long-term risk of malignancy in enterocystoplasty is undefined at this point.^{36,37} All patients who undergo this surgery should be committed to a life of surveillance for this and other potential late complications. Our current recommendations are for patients to have a cystoscopy after 10 years and then every 5 years for life.

CATHETERIZABLE STOMAS

Continent urinary diversions

Gilchrist et al reported augmenting the bladder with the cecum and using the attached ileum as a conduit to

the skin in 1950.³⁸ Some patients had an unexpectedly continent ileocecal valve and required intermittent catheterization of the ileal limb. This technique was left undeveloped until others developed the Indiana pouch utilizing a surgically narrowed ileal limb and a urinary pouch of ascending colon and cecum.^{39,40} This ushered in a number of continent diversions. Koch worked for years on a continent pouch made entirely of ileum.⁴¹ These techniques were almost exclusively applied to cancer patients who underwent cystectomy. They are were applied to children for similar indications such as survivors of rhabdomyosarcoma of the bladder.⁴²

MITROFANOFF

Mitrofanoff described an extra-anatomic channel for catheterizing the bladder in 1980.⁴³ He utilized the appendix which was mobilized on its blood supply, opened at each end, and anastomosed to the bladder and abdominal wall skin (Figure 30.3). This was originally done combined with a bladder neck closure to allow a continent diversion. Mitrofanoff's contribution was popularized by Duckett and Snyder and labeled the Mitrofanoff principle.⁴⁴ While CIC, introduced by Lapides et al in 1971, revolutionized dysfunctional bladder management it was not for all patients.⁴⁵ Catheterization of the adolescent or adult male urethra is not easy in all patients and catheterization of wheelchair bound patients requires them to exit their chair and find a suitable surface to lie on for catheterization. Mitrofanoff's channel allowed patients to catheterize without having access to the urethral meatus and avoided the technical problems of the male urethra.

After a mechanical and antibiotic bowel prep the appendix is mobilized from the cecum while preserving the appendiceal artery found in the mesentery. This vessel is dependable and usually long enough to allow good mobility of the appendix. There are several branches of the artery which form an *arcade* to the appendix and some branches may be divided to allow the appendix to be more easily implanted into the bladder or to allow it to pass more easily through the abdominal wall to the stoma. The appendix is usually removed from the cecum flush with the bowel wall, but if the appendix is short a flap of bowel can be harvested in continuity with the appendix which can then be tubularized as an extension of the appendix. The cecum is closed in layers and the mesentery approximated to prevent internal hernia. The distal tip of the appendix is excised and the appendix is irrigated with antibiotic solution to flush out fecal material and to limit bacterial contamination. The appendix must be catheterized prior to implanting

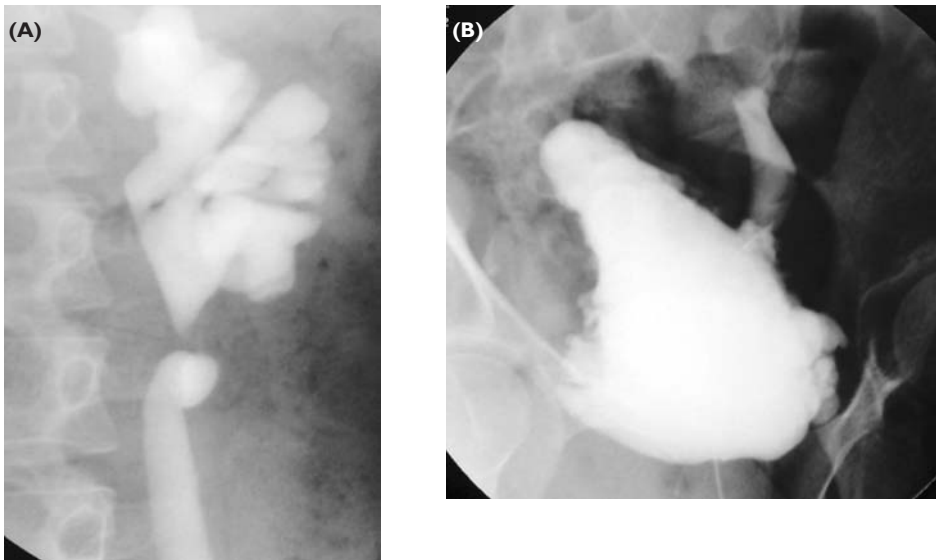


Figure 30.3 (A) Preparation of the bladder with a midline incision extending from just above the bladder neck anteriorly to 3 cm above the trigone posteriorly. (B) The incision creates two lateral bladder flaps. C: Bivalved bladder in preparation for augmentation.

it to ensure that it is patent and of sufficient size to be useful. If the appendix is suitable then it is implanted into the bladder wall using the same techniques as in intravesical ureteral reimplantation.

Choice of site and direction of the anastomosis is critical. We choose to hold the distal appendix at the site of the planned stoma and hold the bladder wall in the position where it would be when full. The channel should then pass in a straight line between the stoma and the bladder to avoid kinking. After the site and path of the channel have been chosen a hemostat is passed through the bladder wall and a submucosal tunnel is created directly in line with the path of the channel outside of the bladder. The opening in the bladder wall must be large enough not to kink the channel. The appendix can then be passed through the bladder wall and down through the submucosal tunnel to be trimmed and sewn to the detrusor at the site of the intravesical opening of the channel. The mucosa of the channel is sewn to the bladder mucosa and the bladder mucosa is closed over the entry site. We choose to sew the appendix to the detrusor outside the bladder and to place several sutures to plicate detrusor muscle over the appendix just outside the anastomosis. The appendix should be made as short as possible to avoid kinking.

During this entire procedure, as with each step of creating any catheterizable urinary channel, the appendix is catheterized repeatedly to ensure that the catheter can pass easily. If at any time the catheter cannot pass easily the last surgical step can be revised to immediately correct problems. Creation of the stoma is a matter of preference. We prefer to place the stoma in the umbilicus and this only requires excision of the base of the umbilicus and anastomosis of the appendix to the

skin of the umbilicus. The ring configuration of the umbilicus tends to keep the stoma open and helps prevent the most common complication of all skin stomas, stenosis. In this technique it is important to excise the complete scar at the base of the umbilicus and sew the channel to viable skin. Alternate stomal construction can utilize a 'V' flap and a spatulated anastomosis. There have been multiple modifications of stomas developed in order to make catheterization easier and to prevent stomal stenosis. The appendicovesicostomy of Mitrofanoff has proven to be durable and reliable.⁴⁶

Yang-Monti

Yang described a bowel reconfiguration technique in 1993.⁴⁷ His paper mentioned but did not feature his channel technique and it went mostly unnoticed until Monti et al did further work with the technique and presented it as an alternative to the Mitrofanoff operation.⁴⁸ The fact was that many patients did not have a suitable appendix because it did not develop adequately, or because of prior inadequate development appendicitis or surgery. The Yang-Monti ileal (YM) channel created an alternative to the appendix and required only a small section of ileum. A 2 cm section of ileum is mobilized on its mesentery after the appropriate bowel preparation. The short cylindrical ileal segment is split on its antimesenteric margin and unfolded into a long thin strip which is then rolled along its long axis to form a long thin cylinder. Once sewn together in this configuration the ileum appears and functions similar to an appendix. By varying where the ileum is incised in relationship to the mesentery the surgeon can determine where the mesenteric attachment lies on the

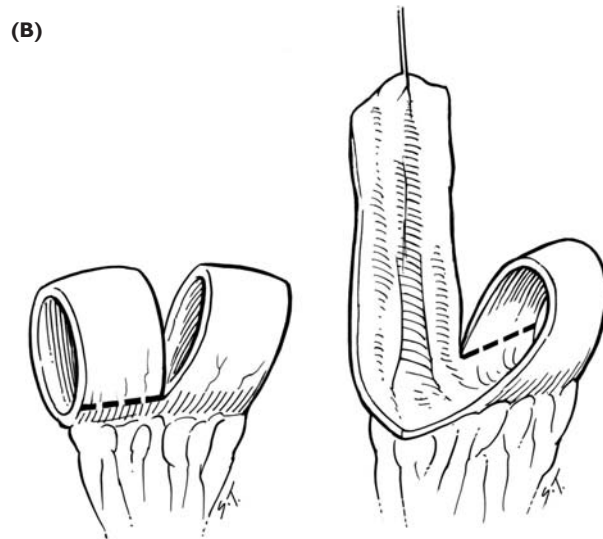
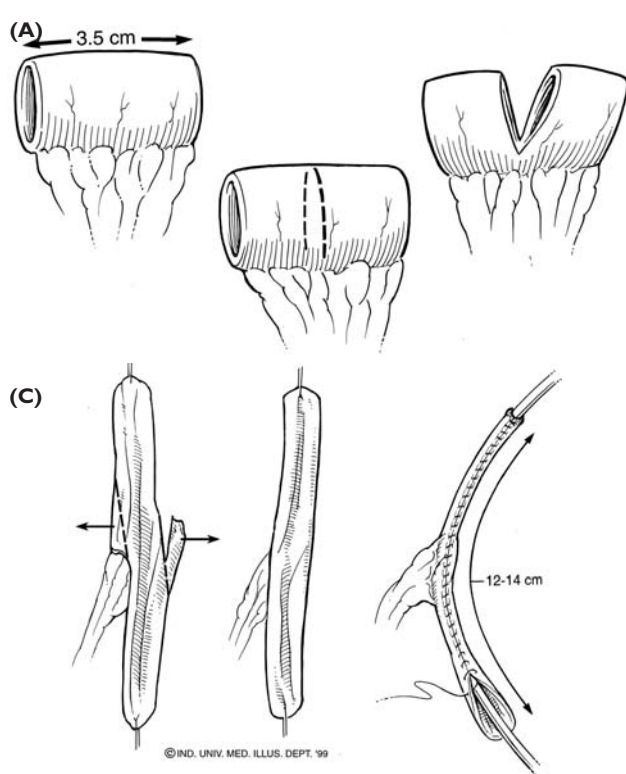


Figure 30.4 MACE (Malone Antigrade Continence Enema). (A) The appendix is mobilized taking care to preserve the mesentery. (B) The junction of the appendix and cecum is reinforced with sutures to prevent leakage from the colon. The appendix is brought to the abdominal skin as a catheterizable stoma.

reconfigured cylinder. The YM channel has been a valuable addition and its long-term outcome data are similar to those of the appendix.⁴⁹ Development of the Malone antigrade continence enema (MACE), which has been effective in management of bowel problems in myelomeningocele patients, has meant that most appendices are utilized for the MACE requiring urinary channels to be constructed of reconfigured ileum.

Casale

There are few problems with the design of the YM channel except for length. The length of the channel was limited by the circumference of the bowel segment utilized. The usual 6 cm YM channel is often inadequate to reach from the bladder to the stoma in many patients. This was addressed originally by sewing two YM channels together in tandem, but there were significant problems with passing the catheter through the anastomosis of the two channels.⁵⁰ Casale developed a technique to reconfigure a slightly longer segment of ileum into a dependable single channel of almost twice the length of the YM tube.⁵² Starting with a 3.5 cm segment of ileum the cylinder is split partially into two segments for about 80% of the circumference leaving the strip of bowel along the mesentery intact. The two partially divided segments are then divided parallel to the mesentery on opposite sides allowing the ileum to unfold in both directions and creating a long thin strip of bowel which measures 9–14 cm in

length. There is some redundancy of the width in the middle which can be excised so that the entire strip is approximately 1.5–2.0 cm wide. The strip is then closed along its long axis creating a channel which can be utilized in most patients. When closing the channel we use interrupted sutures to sew 1.5 cm of each end so that the channel can be easily shortened from either end once it is in position. Effectiveness and dependability of these segments have been similar to appendix.

MALONE ANTEGRADE CONTINENCE ENEMA

Fecal incontinence is a problem that usually accompanies urinary incontinence in neuropathic bladder due to myelomeningocele and sacral agenesis. Enemas delivered per rectum are ineffective due to poor sphincter tone and inability to retain the enema fluid. Malone et al applied the Mitrofanoff principle to the colon and devised a procedure to deliver an enema to the proximal bowel in an antegrade fashion (Figure 30.4).⁵³ The procedure simply mobilizes the appendix in situ, wraps the base of the appendix with cecum to provide a valve mechanism and brings the appendix to the skin as a continent stoma. This patient catheterizes this stoma daily and instills tap water thus producing a thorough cleansing of the colon. This procedure has been very successful and has produced 95% continence rates and almost uniform resolution of constipation in large series.⁵¹

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3 | **Gastrocystoplasty**

Martin Kaefer

GENERAL

Augmentation cystoplasty and continent urinary diversion have greatly improved the quality of life for many children and adults who lack a compliant bladder in which to store an adequate volume of urine.¹ In achieving this goal, bladder induced renal dysfunction can be alleviated and socially acceptable continence achieved. Since the first reported augmentation of a human bladder in 1898, much has been learned regarding the advantages and limitations of, and alternatives to, various forms of bladder augmentation.² The use of stomach for bladder reconstruction was first conceptualized 40 years ago by Sinaiko who showed that in dogs gastric urinary pouches secreted acid in response to meals and that such acidic urine was bacteriostatic.³ This chapter describes the indications for and technique of gastrocystoplasty as well as the unique advantages and disadvantages of this procedure.

POTENTIAL DRAWBACKS OF CONVENTIONAL ENTEROCYSTOPLASTY

The majority of continent urinary reconstructive techniques utilize ileum and colon as the substrate for enterocystoplasty and creation of a continent catheterizable channel. The favorable mechanical characteristics and availability of these two intestinal surfaces lend themselves well to this purpose. However, it has become increasingly clear that there are many potential complications that can occur when placing an absorptive segment of bowel in continuity with the urinary tract.

One of the consequences of conventional enterocystoplasty is the development of acid–base disturbances. The electrolyte abnormality that occurs with the ileum and colon is hyperchloremic metabolic acidosis. It has been reported to be a major problem in as many as 20% of patients who have undergone intestinal cystoplasty.⁴ Mitchell and Piser found that nearly every patient after augmentation with an intestinal segment had an increase in serum chloride and a decrease in serum bicarbonate levels.⁵ However, in their series they found that clinically significant acidosis was rare if renal function was normal. If significant

metabolic disturbances develop and are allowed to persist, a host of problems ranging from progression of renal failure to osteomalacia can ensue. The pharmacokinetics of certain medications can also be altered in patients with enterocystoplasty. This is especially true of drugs that are absorbed primarily by the gastrointestinal tract and are excreted unchanged in the urine.

Bacteria are almost universally present in bladders that have been augmented with ileal and colonic segments. A significant number of patients with intestinal cystoplasty develop pyelonephritis, and 13% have septic and major infectious complications.⁶

One of the consequences of persistent bacteriuria may be the development of struvite (i.e. magnesium ammonium phosphate) stones. Mucus produced by ileum and colon frequently serves as the nidus. In some patients hypocitraturia (resulting in large part from bacterial degradation of citrate) may also contribute to the formation of stones.⁷ Bladder calculi are the most common complication requiring surgery in patients who have undergone bladder augmentation with the incidence ranging from 10 to 50%.^{8–11}

Malignancy can develop when gastrointestinal segments are placed in proximity to the urinary tract. The highest incidence of cancer occurs when the transitional epithelium is juxtaposed to the colonic epithelium and both are bathed by feces.¹² However, enterocystoplasty also is associated with the development of carcinoma.¹³

TECHNIQUE

Anatomy

The stomach can be divided up into three distinct areas, the fundus, body, and antrum. Nearly all of the blood supply reaches the stomach through the celiac axis. The three primary branches are the left gastric artery which supplies the lesser curvature, the hepatic artery from which the right gastric artery arises to eventually branch into duodenal blood supply and the right gastroepiploic, and the splenic artery which supplies the fundus and cardia, and the left gastroepiploic artery. The right gastroepiploic artery anastomoses

with the left gastroepiploic artery, and both supply the greater curve of the stomach.

Operative methods

A number of techniques have been described for harvesting the stomach segment for gastrocystoplasty. Using the gastroepiploic vessels, one can mobilize a pedicle of stomach to the pelvis. Original descriptions of the technique for gastrocystoplasty by Leong and Ong consisted of harvesting the entire gastric antrum and a small portion of the body.¹⁴ Out of necessity the left gastroepiploic artery was always used as the vascular pedicle in this technique. Concerns over the many possible disadvantages of this technique arising from the resultant Billroth I type of anastomosis led to subsequent proposals to use a segment of the greater curvature of the stomach.

Techniques which use a wedge of tissue taken from the body of the stomach have a number of advantages over the original technique. In addition to avoiding the complications of the Billroth I operation, techniques which use a wedge of stomach along the greater curvature have the advantage of being able to base the transfer of the segment off either the left or right gastroepiploic vessels (Figure 31.1). This procedure also utilizes a portion of the stomach with a higher density of acid-producing cells.

The segment generally measures between 10 and 20 cm along the greater curvature. The incision into the stomach is stopped just short of the lesser curvature in order to preserve vagal innervation and normal gastric emptying (Figure 31.2). The right artery is commonly dominant and therefore is more frequently used. Branches of the left gastric artery on the lesser curvature of the stomach just cephalad to the apex of the wedge may be suture ligated in order to avoid significant bleeding. In order to avoid spilling gastric contents and limit bleeding from the stomach surface, parallel atraumatic bowel clamps are placed on either side of the proposed gastric incisions (Figure 31.3). The native stomach is closed in two layers using permanent sutures on the outer seromuscular layer.

Branches of the gastroepiploic artery to the antrum on the right (when basing the blood supply on the left gastroepiploic) or to the high corpus on the left (when the right gastroepiploic is utilized) are divided to provide mobilization of the gastroepiploic pedicle. In order that the eventual pedicle is long enough to reach the bladder, the appropriate segment may be higher on the greater curvature if the right vessel is used as a pedicle, or lower if based on the left. The omentum is left attached to the gastroepiploic vessels and helps secure and support them

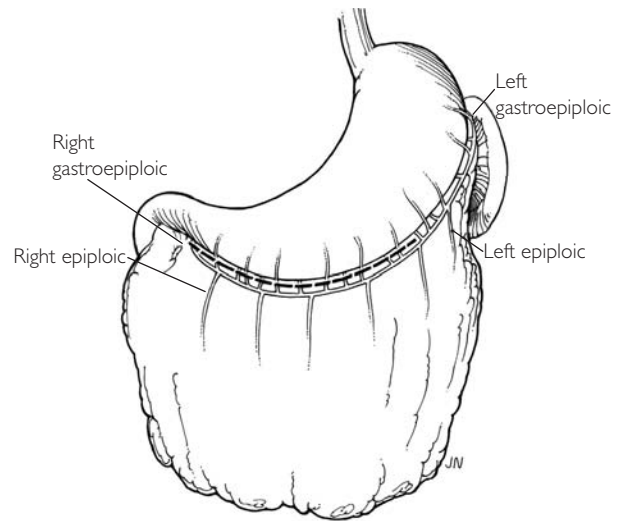


Figure 31.1 Anatomy and vascular supply to the greater curvature of the stomach. Dashed line delineates small vessels that would be divided for a tissue transfer based on the right gastroepiploic vessel.

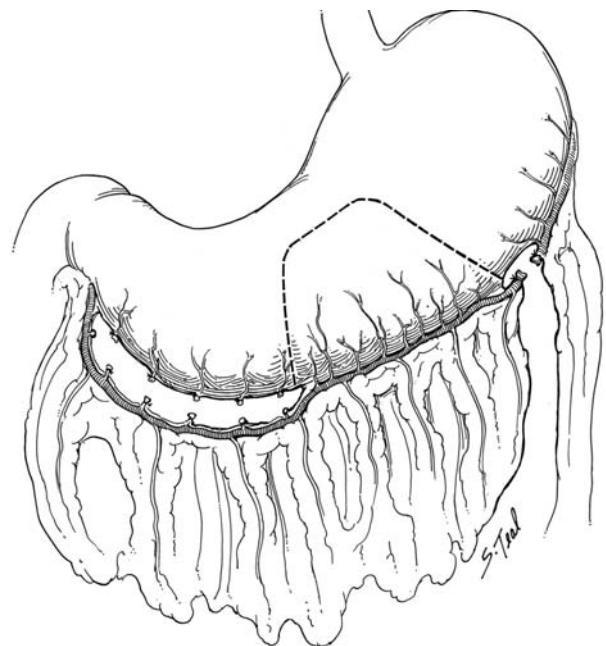


Figure 31.2 Gastrocystoplasty: dashed line indicates segment of stomach that will be used for gastric augmentation. Note that smaller vessels along the greater curvature of the stomach have been ligated and divided to provide increased mobility to the gastric vascular pedicle based on the right gastroepiploic vessel.

(Figure 31.4). It may be necessary for proper pedicle mobility to detach the omentum from the colon along the avascular plane located at the point of its attachment to the transverse colon. The vascular pedicle, with omentum, should not be free-floating through the abdomen.

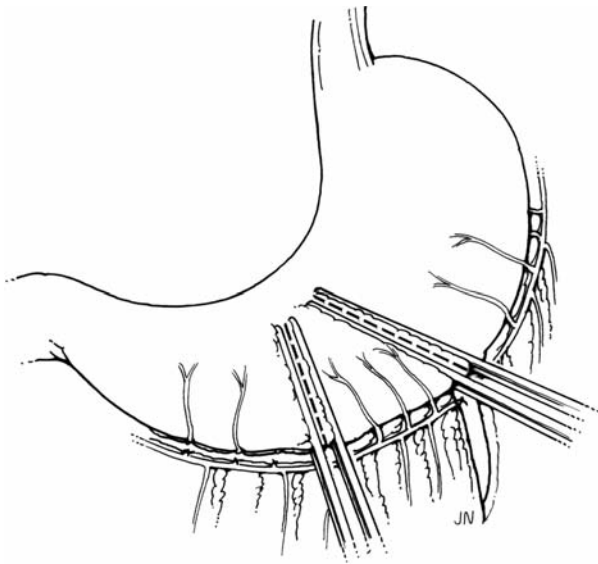


Figure 31.3 Parallel atraumatic bowel clamps placed on either side of the proposed gastric incisions in order to avoid spilling gastric contents and limit bleeding from the stomach surface.

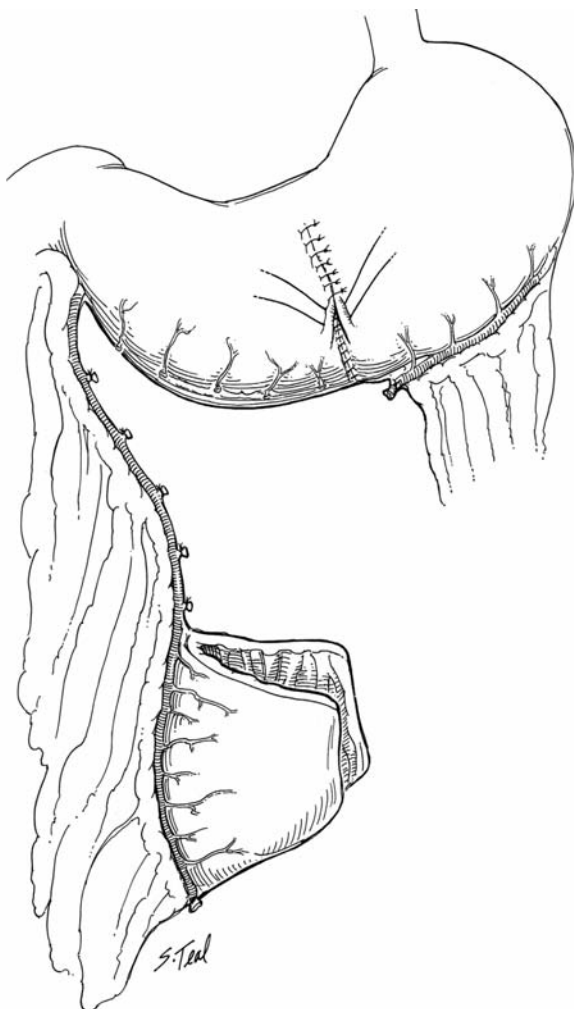


Figure 31.4 Gastric segment based on the right gastroepiploic vessel. Two layer closure of the stomach.

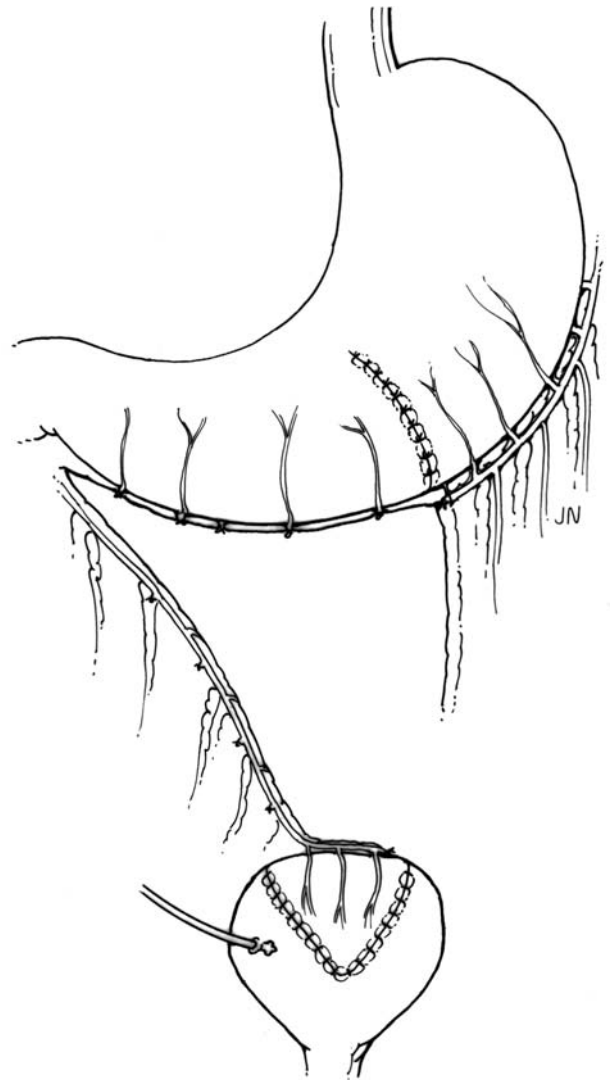


Figure 31.5 Gastrocystoplasty completed.

To avoid twisting and kinking of the pedicle it should be passed through windows in the transverse mesocolon and mesentery of the distal ileum and carefully secured to the posterior peritoneum. Securing the pedicle in this fashion places it in a location that is unlikely to be injured during future abdominal exploration and also minimizes the potential for internal hernia formation. On occasion the gastric segment initially does not reach the bladder without tension. Either gastroepiploic artery may be mobilized closer to its origin for further length. The gastric segment is thereafter approximated to the native bladder with one or two layers of absorbable sutures (Figure 31.5).

Additional techniques have been described which use a longer but narrower segment of stomach along the greater curvature.¹⁵ One advantage of these techniques is that gastrointestinal staplers can be used to

simultaneously subtract out the necessary segment for bladder augmentation and close the stomach.

Demucosalized augmentation gastrocystoplasty

Complications that arise secondary to placing a secretory mucosal layer in the bladder (see below in Potential complications section) have led some surgeons to advocate peeling the detrusor muscle off the dome of the bladder, leaving the mucosa intact, and augmenting the bladder with demucosalized stomach.¹⁶ Nguyen et al reported their results in 11 children at a mean follow-up of 23 months.¹⁶ Urinary continence was achieved in ten patients on clean intermittent catheterization every 3–4 hours and one patient was wet due to low urethral resistance. Bladder capacity increased from an average of 109 ml preoperatively to 236 ml postoperatively. No metabolic complications were noted.

In 1999, Carr et al reported the results of eight new patients and the further follow-up of five of the original cohort reported by Nguyen et al. The mean follow-up for the group was 50 months. Of the 13 patients, four required re-augmentation.¹⁷ Although successful autoaugmentation with demucosalized stomach has many theoretical advantages over other forms of enteric augmentation, a number of children will require additional surgery to achieve continence.

Gastric efferent limbs

Stomach can be reconfigured as a tube to be used as a Mitrofanoff continent catheterizable channel. Gosalbez et al reported on 15 patients who received a gastric tube as part of a composite gastric patch. The reported complications included one case each of early traumatic perforation of the tube, distal tube stenosis, and mucosal redundancy.¹⁸ Two of these patients required reoperation. The primary disadvantage of the gastric Mitrofanoff channel is the potential peristomal irritation that results when skin is exposed to the acidic pH of the gastric mucosa.

Postoperative considerations

Postoperative bladder and gastric drainage is no different to that described for intestinal cystoplasty. Histamine type 2 antagonists or proton pump inhibitors are often given in the early postoperative period to promote healing. Intermittent irrigation with a dilute alkaline solution may also be beneficial in some cases.

ADVANTAGES

The primary advantages of stomach over other intestinal segments for continent urinary reconstruction relate to its metabolic properties.¹⁹ The stomach is less permeable to urinary solutes. This characteristic makes the stomach an attractive segment for individuals with pre-existing metabolic acidosis or renal insufficiency in whom hyperchloremic acidosis would be most likely to occur from augmentation with an absorptive bowel surface. Not only does the stomach serve as barrier to the absorption of chloride and ammonium, but also the gastric mucosa secretes chloride.²⁰ This has been shown to benefit animals with renal failure during acid loading.²¹ From a practical standpoint, serum chloride decreases and serum bicarbonate increases after gastrocystoplasty.^{22,23} Ganeson et al demonstrated an improvement in serum bicarbonate levels in nearly every one of 21 patients with renal insufficiency who underwent gastric augmentation.²² Many of the patients who required oral bicarbonate therapy prior to surgery did not require it following gastric augmentation.

The acidic pH of the urine may also reduce the risk of bacterial colonization. Recurrent episodes of symptomatic cystitis occurred in only 8% of patients following gastrocystoplasty at Indiana University. This compares favorably to the 23 and 17% incidence noted in patients with ileocystoplasty and colcystoplasty, respectively.²⁴ The same trend among different bowel segments was noted for febrile infections, although there was no statistically significant difference among the various segments. Medical therapy to reduce gastric acid secretion appears to diminish the protective effect.²⁵

Another reported advantage of a gastric segment includes less mucus production. The mucus that is produced is of lower viscosity than that from the ileum or colon.²⁶ The characteristics of gastric mucus may reduce the need for neobladder catheterization and irrigation.

Patients who undergo gastrocystoplasty have a significantly lower incidence of bladder stones than do those with augmentations which incorporate other intestinal segments.^{8,9} The previously mentioned characteristics of gastric segments including acid secretion, minimal mucus production, and inhibition of bacterial growth undoubtedly contribute to the formation of fewer struvite stones. The rare stone that does form in a gastric augment is typically of uric acid composition.^{8,27} One case of mixed struvite/uric acid stone has been reported by Leonard et al.²⁸ In their series the great majority of patients were reliant on chronic medical therapy to limit gastric acid secretion and as a result may not have benefited from the inhibitory effect of gastric acid

that inhibits bacterial growth.²⁸ Calculi have also been reported with increased frequency in patients who empty via a continent catheterizable channel and/or have had bladder neck reconstruction presumably due to less efficient emptying of the reservoir.^{8,9}

The availability and accessibility of the stomach as a substrate for augmentation may be seen as an additional advantage in select patients. In patients in whom shortening of the bowel may be expected to lead to degrees of malabsorption (e.g. short gut that can often be seen in cloacal exstrophy), the use of stomach is an attractive alternative. In patients who have required abdominal radiation for treatment of malignancy, the stomach may provide healthy non-irradiated tissue to use in performing continent diversion. Finally, in patients who have previously undergone numerous abdominal operations with resultant severe abdominal adhesion formation the stomach is generally free of the fibrotic process and can be easily mobilized.

Gastric segments, because of their thick seromuscular layer, provide increased versatility when performing reconstructive surgery. Concomitant ureteral reimplantation or creation of a continent catheterizable channel into the reservoir of a patient with a small or non-existent bladder is much easier into a gastric segment than either ileum or colon. The mucosal layer is easy to dissect off the lamina propria and the substantial muscle provides a reliable backing for creation of the flap-valve mechanism.

From a urodynamic standpoint stomach has many theoretical advantages over other bowel segments as a substrate for bladder augmentation. Stomach has fewer intrinsic contractions, the diamond-shaped patch does not have to be reconfigured (resulting in fewer suture lines) and the spherical reservoir created by the patch is the most efficient way to store fluid.

POTENTIAL COMPLICATIONS

Despite the many theoretical and real advantages of gastrocystoplasty, there are clearly some significant disadvantages. The same properties that make stomach an attractive segment for patients with renal failure can under certain circumstances ironically prove detrimental. Secretion of hydrogen and chloride can result in hypochloremic, hypokalemic metabolic alkalosis. In patients with adequate renal function bicarbonate excretion likely serves to prevent this complication.²⁹ However, in patients with renal failure in whom bicarbonate excretion is impaired, a severe metabolic imbalance can ensue. Families should be made aware of this potential problem, which often occurs following

gastrointestinal illness (due to excess losses of solute from the gastrointestinal tract) because it has been reported to occur intermittently in up to one out of every four patients.²² Proton pump blockers (omeprazole), histamine type 2 (H2) inhibitors, and acidification of the serum may prove successful in preventing recurrent episodes. In severe recalcitrant cases the segment may have to be removed.³⁰

Another complication specific to the use of stomach is the hematuria-dysuria syndrome.²⁶ Symptoms of this syndrome include bladder spasm; suprapubic, penile or periurethral pain; coffee brown or gross hematuria without infections; and skin excoriation, and/or dysuria without infections.³¹ Acid secretion by the gastric mucosa produces occasional hematuria and dysuria in nearly all patients with intact sensation.²⁸ The need for medical management to control symptomatic hematuria-dysuria varies considerably between series. Nguyen et al found that nearly one-third of patients develop significant signs and/or symptoms of hematuria-dysuria and that nearly 15% required medical therapy for these symptoms.³¹ In the series from Leonard et al, 70% of patients were reliant on medication to control gastric acid secretion at an average 45 months follow-up.²⁸ In contrast, Plaire et al found that only 4% required medication for persistent symptoms.²⁶ Children who had a sensate urethra (14 of 40, 35%) were more likely to have the hematuria-dysuria syndrome when compared with those with an insensate urethra (three of 32, 9%) ($p = 0.01$). It is imperative to achieve reliable urinary continence in patients undergoing gastrocystoplasty, because urinary leakage may result in exposure of the urethra and perineal skin to gastric secretions. The hematuria-dysuria syndrome generally responds to aggressive therapy with medications that reduce acid secretion by the gastric segment. Proton pump inhibitors and H2 antagonists can reverse the symptoms in most patients. In recalcitrant cases intermittent bladder irrigation with an alkaline solution (e.g. baking soda in solution) may provide symptomatic relief.

In 1999, Celayir et al demonstrated the presence of *Helicobacter pylori* in the gastric segment of patients with gastric augmentation.³² These authors proposed that the presence of this organism may play a role in increasing acid secretion in gastrocystoplasty. Based on their findings, treatment of patients with recalcitrant hematuria-dysuria syndrome for *H. pylori* infection may be a consideration before surgical revision is contemplated. Convincing evidence that *H. pylori* infections play an etiologic role in gastric carcinoma in native stomach raises additional concerns for patients who have this organism in the ectopic gastric segment. The potential for development of neoplasia following

gastrocystoplasty is supported by multiple animal models.^{33–35} To date, there have been two reported cases of adenocarcinoma identified in patients with gastrocystoplasty (one other case of transitional carcinoma in a 73-year-old female has also been reported). One case occurred in a 64-year-old man with a history of spina bifida 10 years after surgery and the other in a 36-year-old man with spina bifida 14 years after gastrocystoplasty.^{36,37} In both patients the tumor was muscle invasive at the time of diagnosis. One patient developed metastatic disease following cystectomy. These cases underscore the importance of periodic endoscopic surveillance.

Despite the theoretical advantages of stomach from a urodynamic standpoint (i.e. fewer mass contractions) rhythmic contractions have been noted on postaugmentation urodynamic evaluation in up to 60% of children.^{19,38–41} The magnitude of these contractions appears to correlate with the size of the segment used for augmentation (i.e. the larger the segment used the less prominent the contractions).^{41,42}

Failure to store adequate urine volumes under low pressure can result in conditions that would theoretically increase the chance of perforation. Failure to achieve a low pressure intravesical environment due to high amplitude gastric segment contractions will increase the stress on the bladder wall. Patients with inadequate outlet resistance who fail to maintain adequate intravesical urine pose an additional threat to bladder integrity. Undiluted acid secretions will result in chronic exposure of the gastric segment and bladder to a higher concentration of acid. Reinberg et al reported perforation of a gastric segment in a defunctionalized bladder after gastrocystoplasty.⁴³ Animal experiments have shown that up to one-third of defunctionalized gastric augmentations will develop significant ulceration which may lead to perforation.⁴⁴ Use of H₂-blockers resulted in some protection for the animals; however, such a clinical situation should certainly be avoided.

In the original description of gastrocystoplasty by Leong the antrum was used and a Billroth I anastomosis was utilized to re-establish gastrointestinal continuity.¹⁴ Although use of the antrum for gastrocystoplasty is rare today it is important to understand the complications unique to this technique. Early complications of Billroth I gastroduodenostomy include gastric retention secondary to atony of the stomach or edema of the anastomosis and duodenal leakage. Delayed complications include the dumping syndrome, steatorrhea, and megaloblastic or iron deficiency anemia.

Postoperative bowel obstruction occurs with an incidence of 10% (two of 21 patients).⁴⁵ It is imperative

that the gastric pedicle be meticulously retroperitonealized in order to avoid herniation of small bowel under the pedicle.²⁸

Composite reservoirs

Many of the complications experienced in gastrocystoplasty (i.e. acid–base, hematuria-dysuria, urodynamic) can be alleviated or avoided by incorporating a segment of absorptive bowel into the augmentation cystoplasty. This augmentation strategy may serve to buffer the acid–base disturbances that can develop after placement of a gastric segment in contact with the urinary tract. Austin et al reported on nine adult patients with a mean follow-up of 54 months who underwent construction of a continent composite reservoir, gastroileal in seven and gastrocolonic in two.⁴⁶ All nine patients had either pre-existing metabolic acidosis or a short bowel syndrome. All nine patients achieved electrolyte neutrality, and the postoperative serum pH was significantly improved.

CONCLUSION

In the above discussion on the unique properties of gastrocystoplasty it is clear that there are many advantages as well as potential disadvantages to using this segment. In deciding whether to use stomach it should be remembered that there is no single bowel segment that is perfect for augmentation in all patients. Patient diagnosis, anatomy, and physiology should all be considered when deciding what is appropriate based on an individual's own circumstances. The primary goal of augmentation is to create a low pressure environment for urine storage that protects the upper tracts and helps achieve urinary continence. Gastrocystoplasty, either alone or in combination with other enteric segments achieves these goals in the majority of cases. Plaire et al, in the largest series of gastrocystoplasties reported to date, noted an 88% continence rate in their 72 patients available for long-term follow-up.²⁶ The high success rate led the authors to propose gastrocystoplasty as a primary alternative for those patients who are continent and have an insensate urethra (i.e. those who are unlikely to develop symptomatic hematuria-dysuria syndrome). Most other major series have also reported continence results in the 80–90% range.^{19,28} Many patients who require gastrocystoplasty have upper tract changes due to high-pressure bladders. Many series have shown stabilization or improvement of upper tract hydro-nephrosis in the majority of patients who have undergone gastrocystoplasty.²³

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32 Ureterocystoplasty

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HISTORY

The ideal bladder replacement or augmentation component for reconstruction of the lower urinary tract has long been a challenge to the urologist. The most common reasons for performing augmentation cystoplasty in the pediatric population have been for a high pressure, poorly compliant bladder, and/or inadequate bladder volumes. In such scenarios the lower tract can either negatively affect the kidneys or render the patient incontinent. Most commonly children who might require augmentation have bladder dysfunction associated with neurogenic bladder, posterior urethral valves, bilateral ureteral ectopia, or the bladder exstrophy complex.

In general, various segments of bowel, from stomach to large bowel, have been utilized when cystoplasty is required in children and adults. Despite being able to create reservoirs of adequate capacities and pressures, due to the inherent secretory and absorptive properties of the various bowel segments that have been historically utilized in enterocystoplasty, short- and long-term complications are common. The well recognized disadvantages of augmentation bowel cystoplasty include mucus production, electrolyte disturbances, malignant potential, spontaneous perforation, calculus, altered drug metabolism, and bacterial colonization, as well as true urinary infection.

The ideal bladder replacement would be composed of material that behaves like true bladder, that is, it neither secretes nor absorbs. Active investigation examining various other materials has been undertaken in animal models, including using synthetic materials. Indeed tissue engineering techniques have now been employed clinically in order to regenerate the patient's own bladder *ex vivo* and then implant the tissue as a cystoplasty component. Clearly this is the future, but data and experience to support this avenue as a mainstream option for bladder replacement or enlargement are lacking at present.^{1,2}

The ureter is an ideal tissue for bladder augmentation as it is lined with native transitional epithelium (does not absorb or secrete), has muscular backing, is compliant, and, if available, avoids the need for

harvesting a bowel segment. Moreover, there is likely no increased risk of carcinogenesis using allogeneic, transitional epithelium lined tissue. Unfortunately, the ureter is not readily available in most patients for the purpose of augmentation and inappropriate patient selection has led to poor results. Experience with this form of augmentation has evolved since it was first described by Eckstein in 1973.³ It was not until the 1990s that Bellinger re-popularized this technique and Koyle described its utility in the end-stage renal disease population.⁴⁻⁶ It is now apparent that ideal patient and system selection is paramount to the success of this type of augmentation.

SYSTEM SELECTION

Augmentation should never be undertaken lightly, especially in the pediatric age group. Families and patients must be evaluated to ensure their compliance with the possible need for intermittent catheterization, and that they know that life-long follow-up is mandatory and that complications and multiple surgeries are extremely likely. Upper tract imaging and voiding cystourethrography (VCUG)/video urodynamics should be performed in order to assess the bladder and outlet status as well as the anatomy and caliber of the ureter(s) and the presence of reflux.

Ureterocystoplasty is clearly not the ideal procedure in every situation, as an appropriately dilated ureter(s) is required. If the function of one or both kidneys is in question, this should be addressed. Ideally, if a unilateral nephrectomy is indicated, the entire ureter and the renal pelvis can be utilized for the augment. The size of the augmenting system must be large enough to buffer high bladder pressures and achieve adequate volume continence. It is well established that detubularization of a cylinder which is then reconfigured as a sphere increases the volume dramatically by at least a factor of the radius. Initial reports described nephrectomy with the use of an entire ureter and renal pelvis with preservation of the proximal ureteral blood supply when ureterocystoplasty was to be performed.^{4,7} Subsequent authors have shown good results with

preservation of the ipsilateral kidney and use of the distal ureters for ureterocystoplasty.⁸ This is not appropriate in every case as demonstrated by Gosalbez and Kim, who unfortunately did not find progressive dilation of the augment that had been anticipated when patients were followed for periods of 6–24 months. They emphasized the critical importance of using a sufficiently dilated ureter to ensure the best results. Other studies have shown success with varying diameters of ureteral dilation. Pascual et al reported good clinical results with acceptable catheterization intervals when ureters ranging from 0.8 to 2.5 mm in diameter and lengths measured during surgery of 9–14 cm were utilized.⁹ Perovic et al suggested that ureters could be dilated further if initially they were diverted to the skin with cutaneous loop ureterostomies, using prostatic balloon catheters. These ureters were then used for ureterocystoplasty and this has also been demonstrated in the rabbit model.¹⁰ Not all authors have had universal success with less dilated ureters. Landau et al described a failure when transureteroureterostomy was performed and the distal ureter used for augment.¹¹ The patient had persistent incontinence and poor compliance postoperatively, and ultimately required ileocystoplasty. It was emphasized, as a result, that ureterocystoplasty should only be considered in massively dilated ureters.

Attempts have been made to expand the undilated ureter in order to potentially expand the utility of ureterocystoplasty. These techniques of dilatation have not been embraced as being successful.^{12,13} Lailas and Atala on the other hand, also studied progressive ureteral dilatation and suggested that the ureteral size can be expanded at least tenfold.¹⁴

In order to provide more general guidelines for ureteral augmentation, Husmann et al investigated predictors of success.¹⁵ In this multi-institutional study, capacity of the augmenting ureter(s) was the primary determinant of success. When the ureteral diameter was measured preoperatively, it was found that the most successful augments were performed with distal ureteral diameters of 1.5 cm or more. This did not translate to the addition of the diameter of two distal ureters, even if they both added up to more than 1.5 cm. In cases of large refluxing megaureters in which the entire ureter is to be used, preoperative urodynamics will confirm the potential buffering capacity of the dilated ureter(s) and bladder. If an entire single system is to be used, this study found that ureterocystoplasty was most effective in patients who had normal to mild non-compliance, defined as greater

than 20 ml/cmH₂O.¹⁵ Pascual et al reported similar successful augmentations with refluxing megaureters, an average increase in capacity of 177% at less than 30 ml/cmH₂O.⁹ Of these patients 14 of 22 had refluxing megaureters and all 22 had transureteroureterostomies at the time of augmentation which allowed for a longer length of ureter for the augment. Of the patients in Husmann et al's study with severe non-compliance defined as less than 20 ml/cmH₂O, 21/26 patients had either been reaugmented or were pending reaugmentation.¹⁵

TECHNIQUE

Ureterocystoplasty can be performed via an extraperitoneal or an intraperitoneal approach. The cystotomy and distal ureteral dissection can be performed through a Pfannenstiel incision in small children with a separate flank incision for nephrectomy. A larger midline abdominal incision may be needed in an older child or if a transureteroureterostomy is to be performed, although the procedure is increasingly being performed with a retroperitoneal approach in appropriate patients.^{10,16} In order to minimize incisions and potential morbidity, the upper tracts can be approached laparoscopically and the upper ureters can then be mobilized in a less invasive manner. The reconstruction can then be performed via a more limited lower abdominal incision.

The ureter should be opened along its antimesenteric border, and careful attention should be paid to preserving the blood supply. The usual blood supply to the ureter is derived from the renal, gonadal, and internal iliac arteries.^{17,18} Previous surgery at the ureterovesical junction does not preclude ureterocystoplasty because of the collateral flow between these vessels.¹⁷ Many variations using ureters with surgically altered blood supply have been reported with good results.^{8,19,20} Adams et al and others have demonstrated that the distal ureter can be left intact which avoids dissecting the distal blood supply to the ureters from the iliacs.^{9,21,22} Video urodynamic studies showed the distal ureter filling and emptying well with no risk of subsequent complication. A single case of pyelonephritis occurred in a patient and may have been related to other factors, including bacteriuria from clean intermittent catheterization (CIC).²¹

Various combinations and amounts of ureters have been used for augmentation. Initial reports

described ureterocystoplasty in patients with dilated megaureters who required nephrectomy. In these cases, the entire ureter and renal pelvis can be used for augment after nephrectomy, using the distal blood supply to the ureter.⁷ Soon after, authors described the successful use of partial ureters combined with transureteroureterostomies or ureteronecystotomies.^{1,4,9} Gosalbez and Kim described using bilateral dilated and tortuous ureters by performing a transureteroureterostomy and then detubularizing the distal remaining ureter to make the patch.⁸ Krstic described the use of bilateral megaureters in which the distal ureters were dissected from the bladder.¹⁷ The ureters were dissected extraperitoneally for 7–8 cm, opened along their anteromedial border, and then intussuscepted to form an antirefluxing nipple. The most distal portion of the ureters was joined to create a patch that was anastomosed to the bladder. In this fashion augmentation can be accomplished with systems that have had previous surgery at the ureterovesical junction, as the blood supply is maintained from the proximal blood supply in the renal and gonadal arteries. Churchill et al described the use of an entire ureter and renal pelvis in a 15-year-old child who had previously had bilateral ureterostomies and ureteronecystotomies.²⁰ The segmental arteries to the kidney were ligated during the nephrectomy, but preservation of the main renal vessels and blood supply to the renal pelvis and proximal ureter allowed use of the entire system, relying on blood supply from the renal and gonadal vessels. Reinberg et al described ureterocystoplasty in six children with posterior urethral valves and with neurogenic bladders who also had vesicoureteral reflux and renal dysplasia (VURD) syndrome. They suggested the use of a modified Pfannenstiel incision combined with a posterior approach for the nephrectomy, which may have minimized postoperative pain and hospitalization.²³ Children with bladder exstrophy have also successfully undergone ureterocystoplasty.²⁴ Unlike the valve patient with VURD syndrome, such patients rarely have massively dilated ureters of adequate caliber to allow this procedure to be performed.

URETEROCYSTOPLASTY IN END-STAGE RENAL DISEASE

The patient with end-stage renal disease (ESRD) presents a challenge when augmentation might be

considered. Historically, bowel has been used cautiously in this group because of its absorptive and secretory capabilities, and the associated metabolic sequelae that are exacerbated due to the reduced buffering capabilities in the diseased kidneys. Thus, ureterocystoplasty provides a perfect solution in this group, when dilated ureter is available. This can be a difficult group in which to assess continence, especially when kidneys are massively dilated and concentrating ability is lost with ensuing nephrogenic diabetes insipidus. Thus, with good compliance and combined bladder and ureteral capacity, augmentation may not result in the patient who makes copious amounts of urine becoming continent. Therefore judgement must be used in deciding whether reconstruction should be performed in the pre- or post-transplant situation, if the indication is continence only.

If volumes are truly inadequate or bladder compliance is an issue even with non-detubularized ureter, then it has been our preference to proceed with pretransplant ureterocystoplasty in order to prepare the patient for renal transplantation. This is almost always a patient with posterior urethral valves, although we have also used the massively dilated ureter in patients for pretransplant augmentation in children with non-neurogenic neurogenic bladder (Hinman's syndrome) and prune belly syndrome.^{5,6} We prefer ensuring that native urine is still filling the bladder cyclically whenever possible, rather than performing nephrectomy. This enables the patient with renal insufficiency to be allowed a more liberal fluid intake in addition to preserving whatever positive metabolic function the damaged kidney might be performing. It also allows us to ascertain whether the patient can empty his/her bladder effectively or whether CIC programs might be necessary. We think that native nephrectomies can always be performed after or during the allograft placement. Furthermore, we believe that whenever we perform augmentation of any kind in children, regardless of whether a bowel segment or ureter is used for augmentation, or whether a patient has renal dysfunction or normal kidneys, that a Mitrofanoff suprapubic catheterizable stoma should be performed.⁶ This allows a safety valve access site for self catheterization and indeed, in our population, has been preferred over urethral access when CIC is indicated and both routes are available. Ureterocystoplasty has been performed successfully as a coincidental procedure with planned living related renal transplantation.²⁵

In occasional patients who have undergone ureterocystoplasty, the muscle backing from the ureter itself has been sufficient to allow an extravesical non-refluxing reimplantation of the ureter to be performed at the time of renal transplantation.⁵

Studies of patients with non-compliant, high pressure bladders have shown that bladder augmentation using dilated upper tracts achieves an excellent functional result with few complications and that these patients can go on to successful renal transplant.²⁶ The most common complication was asymptomatic urinary tract infection. Two patients no longer had dilated ureters by the time they required augmentation cystoplasty, one who underwent a cutaneous loop ureterostomy and another with neurogenic bladder from medullary syndrome. They both had their upper tracts 'redilated' prior to performing cystoplasty. This was accomplished with saline antibiotic solution instillations into the cutaneous ureterostomy and saline bladder cycling into the neurogenic bladder. All patients had VUR grade IV–V in one or both systems. When nephrectomy is being considered in end-stage renal patients, the bladder should be evaluated first, in case the dilated ureter and renal pelvis could be used to augment the bladder.²²

COMPLICATIONS

There have been few complications reported with ureterocystoplasty. Those that have been reported include two cases of spontaneous perforation.^{9,15} Others have reported ureteral obstructions at the site of ureteral reimplant requiring stent placement or ureteroneocystotomy.¹¹ The low number of complications is likely a reflection of the small number of patients who are appropriate candidates, as well as the ability to stay extraperitoneal in many cases, and to avoid the harvesting and anastomosis of bowel, not to mention the issues that are related to mucus secretion of bowel and its metabolic issues.

The major complication in ureterocystoplasty is improper patient selection in not choosing a patient with massively dilated ureters. As Husmann et al have reported, many patients will require secondary bowel augmentation if an inadequate volume of ureter is engrafted as the augmenting segment.¹⁵ As much as ureteral tissue is potentially distensible, there is no guarantee that such dilatation will occur with bladder filling after augmentation.

CONCLUSIONS

Ureterocystoplasty is an effective mode of bladder augmentation in properly selected patients. The most likely beneficiaries of this procedure will be patients with massive ureteral dilatation in association with a diagnosis of posterior urethral valves. Ureterocystoplasty is especially attractive in the patient with impaired renal function due to the absence of secretory and absorptive capabilities that are associated with the alternative choice, bowel. In the appropriate patient, ureterocystoplasty can be performed with minimal risk of complications.

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33 Bladder neck procedures for neuropathic sphincteric incontinence

John C Thomas and Jack S Elder

INTRODUCTION

The bladder outlet is composed of the bladder neck and proximal urethra. This functional unit is of critical importance in maintaining continence during bladder filling, while acting as a compliant tube for urine passage during bladder emptying. Causes of bladder neck incompetence in children include neurologic insult (myelodysplasia), an anatomic insult (exstrophy/epispadias or urogenital sinus), and trauma. The most common problem encountered in children is myelodysplasia, which has a reported incidence of one in 1000 live births in the US.¹

Continence is not synonymous with dryness, as the former implies a functional bladder neck that is closed during filling and opens during voiding.² For example, the goal in a child with exstrophy is voluntary voiding with adequate control (continence). In contrast, clean intermittent catheterization (CIC)³ and advances in catheterizable stomas have shifted the goal in patients with a neuropathic bladder to reconstructing a bladder outlet that allows the patient to be dry without voiding.² Simultaneous bladder augmentation is often performed, as increasing outlet resistance can turn a low pressure reservoir into a non-compliant hyperactive chamber.

If medical therapy (pharmacologic treatment plus CIC) fails, increasing urethral resistance can be accomplished with bladder neck reconstruction/urethral lengthening procedures, periurethral sling, artificial urinary sphincter (AUS), artificial bulking agents, or bladder neck closure.

The bladder outlet can be measured in several ways, including leak point pressure and electromyography. Unfortunately, no criteria predict with 100% accuracy whether the bladder outlet is intact or incompetent. The Valsalva leak point pressure has been reported to be helpful, because it simulates circumstances that cause incontinence, but it has been unreliable in children. The sphincter is easiest to assess with videourodynamics. The bladder outlet resistance may be assumed to be insufficient if the bladder neck is open on fluoroscopy, if sphincter denervation is identified on electromyography, or if the leak point pressure is

less than 30–40 cmH₂O. Some children have both poor bladder compliance and a borderline leak point pressure. In these patients, it is difficult to predict from the urodynamic data whether bladder augmentation alone or combined with a procedure to increase bladder outlet resistance will be necessary for continence. In such cases, the urodynamic evaluation should be performed in two stages: the test is initially performed in the routine manner and then repeated with a balloon catheter occluding the bladder neck. This maneuver offers a better challenge for bladder distention and allows more accurate evaluation of compliance.

Choosing the appropriate outlet procedure should be based on urodynamic evaluation, patient counseling, surgeon experience, individual patient needs, patient manual dexterity, and motivation for continence.⁴ Despite the many options available, a consensus has not been reached regarding the best management of repairing neuropathic sphincteric incontinence.

BLADDER NECK RECONSTRUCTION

A reconstructive procedure to tighten the bladder neck in patients with epispadias was initially described by Young in 1922. This procedure involved excising a full-thickness strip of muscle and mucosa from the bladder neck and proximal urethra and reconfiguring the neourethra over a silver probe.⁵ Dees and Leadbetter made substantial modifications to Young's original description that included lengthening the neourethra by extending the posterior urethral flaps into the bladder, excising the mucosa on these flaps to allow for muscular wrapping of the neourethra, and reimplanting the ureters cephalad to allow for maximal neourethral length.^{6,7}

The Young-Dees-Leadbetter (YDL) bladder neck reconstruction is begun by placing the patient in a hyperextended position whenever possible, because this may facilitate exposure of the bladder neck. The anterior bladder wall is approached with a longitudinal midline incision starting at the beginning of the urethra (Figure 33.1). A 12–14 mm wide strip of mucosa

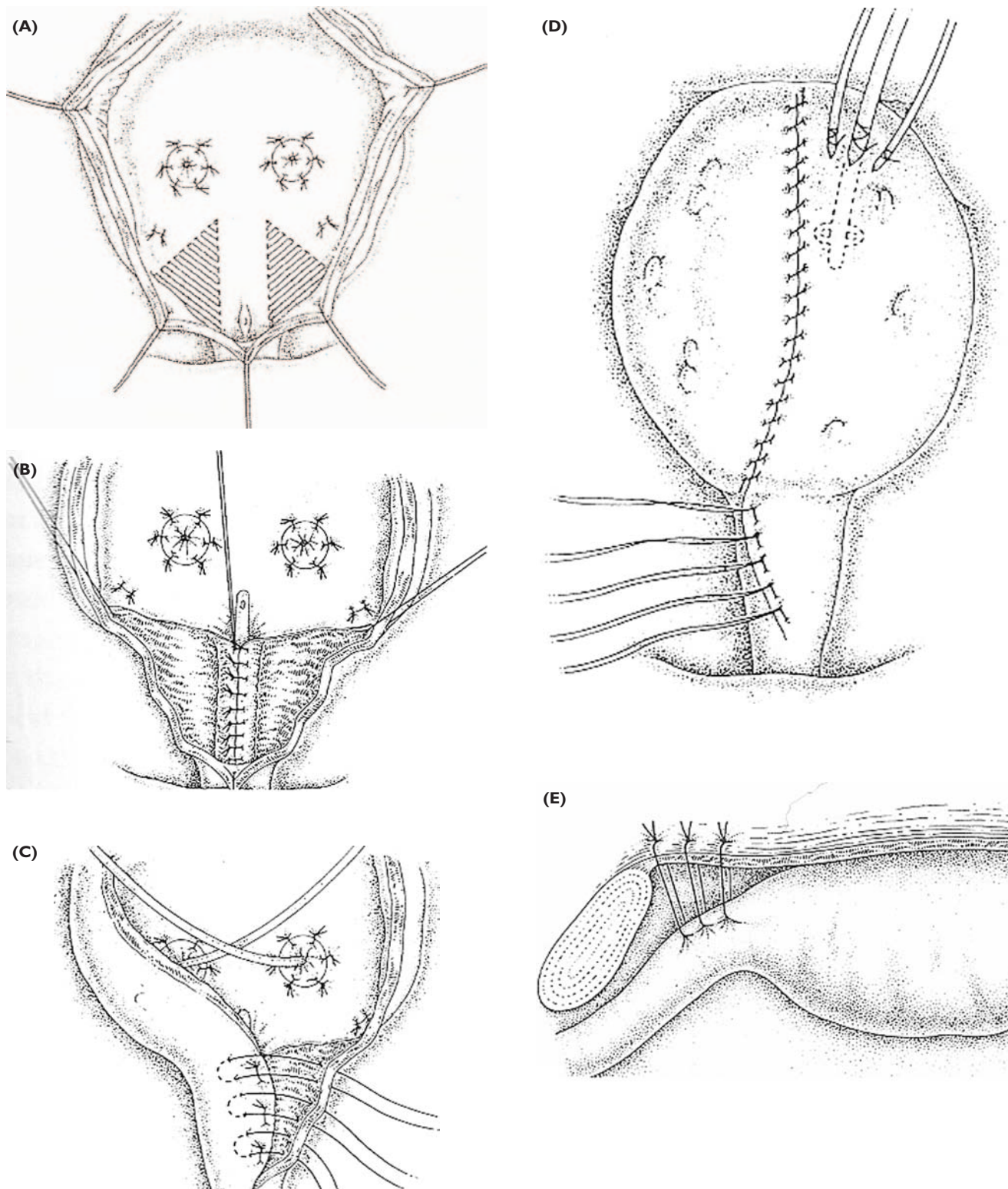


Figure 33.1 Young-Dees-Leadbetter procedure. (A) Two parallel longitudinal incisions are made in the posterior bladder wall, starting at the proximal urethra. Both ureters are disconnected and reimplanted higher in the posterior bladder wall in a cross-trigonal fashion. (B) Both ureters have been reimplanted. The isolated rectangular strip of mucosa is tubularized, leaving a small (8Fr) Silastic tube in its lumen. The mucosa lateral to the edge of the strips is removed. (C) One of the sides of the denuded detrusor is used to wrap the tubularized mucosa, providing increased resistance at the bladder outlet. (D) The other side of the denuded detrusor is sutured over the outer surface of the first flap, avoiding overlapping suture lines. (E) Lateral view. The muscular layer of the elongated urethra is sutured to the undersurface of the pubic symphysis.

is outlined in the midline trigonal area, starting at the proximal urethra. It is important to begin lengthening as far into the urethra as possible to avoid formation of an hourglass deformity, often seen in cases of failed YDL procedure. The mucosa lateral to the edge of the strips is removed, creating triangular areas of denuded detrusor. The ureteral orifices are often located in this area and need to be reimplanted higher in the posterior bladder wall in a cross-trigonal fashion. The isolated mucosal strip is then tubularized using running absorbable sutures over an 8 Fr silicone stent. In difficult cases, additional exposure can be obtained by removing a wedge of bone and cartilage to expose the bladder neck and proximal urethra entirely. One of the sides of the detrusor muscle is cut along the horizontal edge of the denuded mucosa and is used to wrap around the neourethra in a vest-over-pants manner. A similar maneuver is done with the contralateral side of the detrusor, which is then brought around and sutured over the outer surface of the first flap, providing increased resistance at the new bladder neck. The neourethra should be at least 3–4 cm long to provide sufficient urethral resistance. The muscle layer of the neourethra, as well as the new bladder neck, is then sutured to the undersurface of the pubic symphysis, creating urethral suspension. This technical step is important for maintaining the neourethra in an intra-abdominal position and for buttressing it against the undersurface of the pubis to help prevent stress incontinence. The bladder can then be closed or one may proceed with augmentation cystoplasty.⁸

Although currently considered the gold standard procedure in patients with the exstrophy-epispadias complex, success rates of the YDL procedure in patients with neuropathic sphincteric incontinence have been marginal, ranging from 50 to 60%.^{9,10} In the series from Indiana, although 80% of the patients were ultimately dry, 20% of the patients required a second continence procedure and 5% required a third procedure. Augmentation cystoplasty was ultimately required in 90% in this series.¹⁰ Disadvantages of the YDL include the loss of bladder capacity and the frequent need for bladder augmentation and ureteral reimplantation. Success rates for a primary YDL were significantly higher in female than male patients. YDL may be applicable to those who have previously failed other bladder neck procedures and when ureteral reimplantation is required. Difficulty with catheterization has not been problematic.¹⁰

The Mitchell modification of the YDL was described by Decambre et al¹¹ (Figure 33.2). In this procedure, a transverse incision is made through the anterior half of

the proximal urethra. The transverse incision is extended laterally, posteriorly, and cephalad toward the ipsilateral ureteral orifice on each side. The ureters are disconnected and reimplanted by either a Cohen or a Leadbetter technique. The urethra is tubularized over an 8 or 10 Fr catheter using a two-layer running suture. The bladder is closed vertically, and the superior border of the initial incision becomes the bladder dome. Of eight patients with exstrophy/epispadias who underwent the procedure all were continent.¹¹

In an attempt to bolster the YDL repair as well as protect a periurethral plane for a potentially needed AUS, Mitchell and Rink described the placement of a silicone sheath around the YDL repair.¹² Unfortunately, long-term follow-up of these patients showed a high rate of sheath erosion and this procedure is no longer recommended.¹³ Diamond et al have reported greater success with the placement of a thinner silastic sheath interposed with omentum.¹⁴

In the patient with neuropathic sphincteric incompetence, YDL seems most appropriate as a salvage procedure in girls or women in combination with a sling or wrap procedure, in those who need bladder augmentation. It seems contraindicated as a primary procedure and in male patients.

URETHRAL LENGTHENING PROCEDURES

Tubularizing the bladder neck in patients with a neuropathic bladder and creating a tube in continuity with the bladder often fails, as this portion of the bladder tends to open over time.² This situation contrasts with patients with non-neuropathic incontinence, such as exstrophy or epispadias, in whom the goal is increased urethral resistance combined with volitional voiding. Kropp was the first surgeon to apply the flap-valve mechanism to the bladder neck, resulting in complete urinary retention with total dependence on catheterization.

The Kropp bladder neck repair is based on a 6 × 2 cm anterior bladder wall flap that is mobilized in continuity with the proximal urethra, separated from the bladder neck, and then rolled into a tube over a Foley catheter with continuous absorbable suture (Figure 33.3). This tube is brought beneath a broad submucosal tunnel that is developed between the ureteral orifices and the ostium of the tube is sutured to the bladder.^{2,16} This tunnel must be wide and care must be taken to obliterate the dead space at the entrance of the urethra into the bladder to facilitate

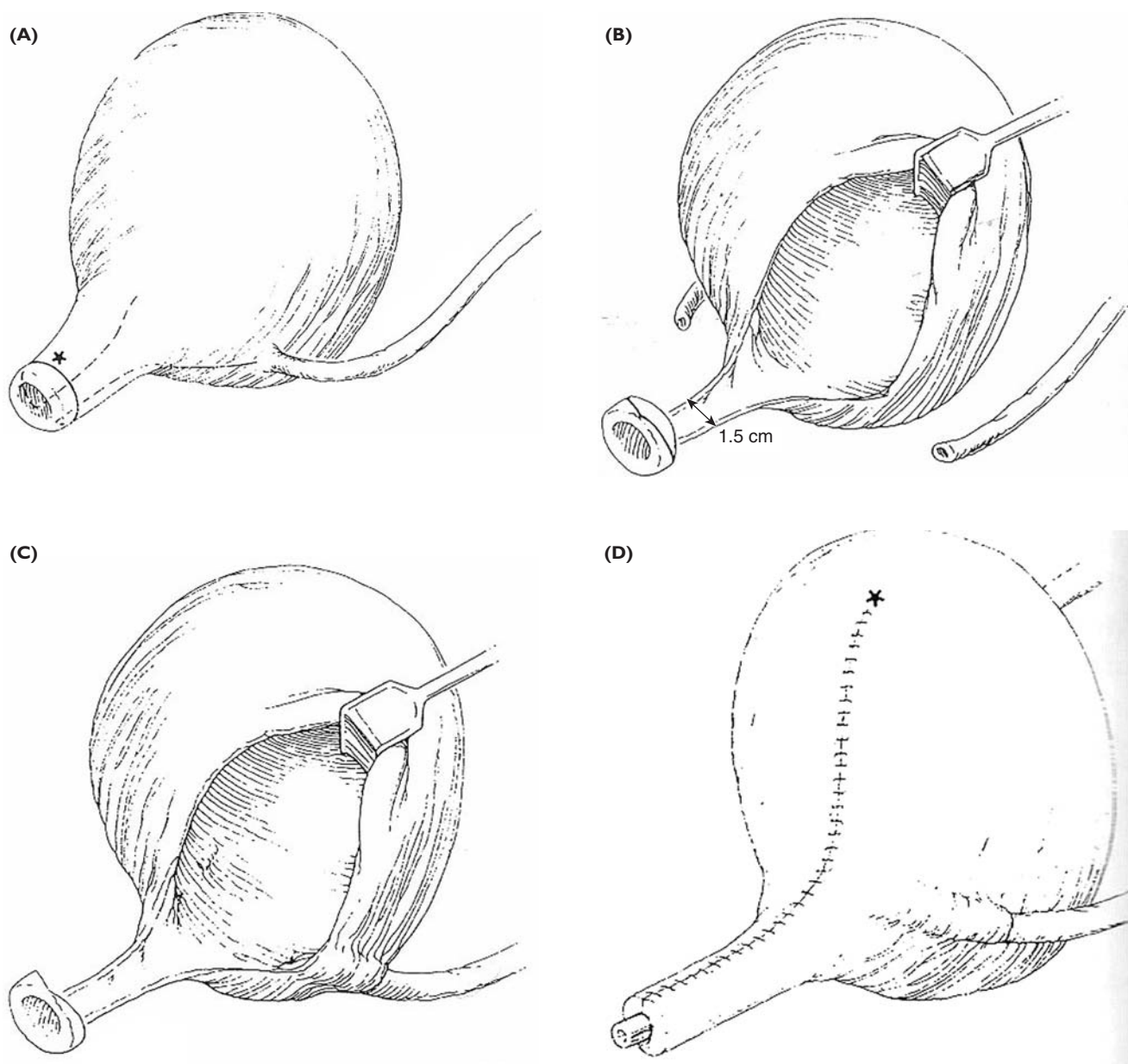


Figure 33.2 Mitchell modification of Young-Dees-Leadbetter procedure. (A) A transverse incision is made through the anterior half of the proximal urethra. (B) The transverse incision is extended laterally, posteriorly, and cephalad toward the ipsilateral ureteric orifice on each side. The ureters are disconnected. (C) The interior of the bladder is exposed by gentle retraction as the incision is elongated. The ureters are reimplanted by either a Cohen or a Leadbetter technique. (D) The urethra is tubularized over an 8 or 10 Fr catheter using a two-layer running suture. The asterisk in (A) shows the area that will ultimately be near the dome noted by the asterisk in (D). Indiana University School of Medicine (C) Copyright 1989. All rights reserved. Reprinted with permission.

catheterization.⁴ The bladder can be closed or one can proceed with an augmentation cystoplasty.^{2,16}

Continence rates have been reported as high as 80–90%.¹⁶ However, some patients have difficulty with catheterization.¹⁷ In addition, because there is no pop-off valve for the urethra, there is an increased risk of spontaneous bladder rupture following augmentation enterocystoplasty. Furthermore, if the patient has

not undergone augmentation, a theoretical concern may be an increased risk of upper tract deterioration if unstable bladder contractions are not controlled pharmacologically.¹⁸

Kropp suggests a few important points to avoid difficulty with catheterization: implant the tube to extend only 2–3 cm above the interureteric ridge to avoid kinking when the bladder is full, remove part of the

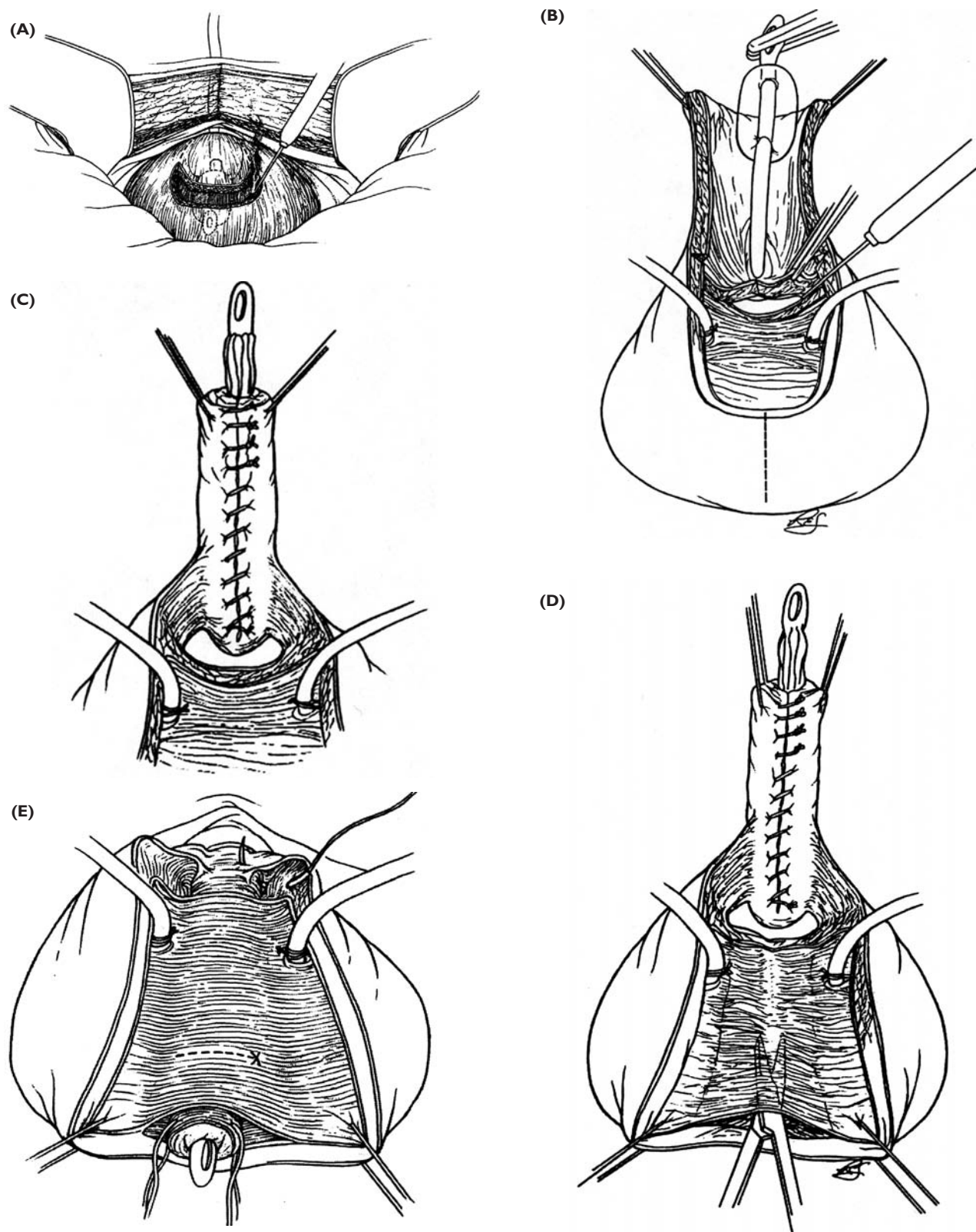


Figure 33.3 Kropp procedure. (A) The anterior bladder wall flap (5–7 cm × 2–2.5 cm wide) is outlined. (B) The junction of the trigone and the bladder neck is identified from within and the mucosa of the bladder neck separated from the urethra. (C) The anterior bladder flap is tubularized with a one-layer suture (interrupted suture in the last 2 cm). (D) A posterior trigonal tunnel (6 × 3 cm wide) is created beginning at the bladder neck and carried upward beyond the ureteral orifices. (E) The tubularized flap is reimplanted in the posterior submucosal tunnel, and the anterior bladder wall is sutured over the bladder neck at the base of the neourethra. From reference 15, with permission.

outer musculature in some of the thick detrusor before fashioning the tube, and leave the neourethra with an intraluminal catheter for 4 weeks after surgery.¹⁹

Because difficulty with catheterization, especially in males, has been problematic, modifications allowing for easier catheterization as well as providing a urethral pop-off have been developed.^{18,20} Snodgrass reported on a modification of the Kropp procedure in which the bladder flap is rolled into a tube, but instead of transecting the bladder neck, it is kept in continuity with the posterior bladder wall. Also, the tube is laid within a trough with bladder mucosa over the tube.^{18,21} These modifications effectively shorten the intravesical length of the tube and decrease the efficacy of the continence mechanism, thus allowing for a 'pop-off valve' with bladder overdistention. Despite these modifications, continence rates have remained at approximately 80%, similar to Kropp's original series.¹⁸

Most cases of difficult catheterization can be managed conservatively with prolonged catheter drainage. Some require endoscopic guidance to traverse the urethral flap-valve.¹⁷ New onset vesicoureteral reflux has been reported; this problem is thought to be secondary to trigonal distortion and not increased bladder pressures.¹⁸

The best candidate for the Kropp procedure or its modification is a male patient who requires intermittent catheterization. Augmentation enterocystoplasty and creation of a continent catheterizable channel also is recommended to maximize the likelihood of success. The Kropp procedure seems unnecessary in girls because other less complicated procedures have a similar success rate. In addition, the Kropp procedure should not be used in an individual who can void spontaneously.

Pippi Salle developed a modification of the Kropp procedure in which an onlay flap is created from the anterior bladder wall and is sutured to a posterior bladder mucosal flap using anterior and posterior based bladder flaps, thus keeping the urethra in continuity with the posterior bladder wall²² (Figure 33.4). Briefly, a 2 × 6 cm full-thickness anterior bladder wall flap is mobilized similar to the method of Kropp. However, instead of rolling this into a tube, parallel incisions are made in the mucosa of the posterior bladder wall between the ureteral orifices. The flap mucosa is then sewn directly onto the posterior flap in two layers. The lateral mucosal detrusor flaps are then mobilized to cover the new lengthened urethra. Continence has been reported in 70% of patients with none reporting difficulty with catheterization.²³ Similar results were noted in a small series from Indiana.²⁴ The main early complication noted has been urethrovesical

fistula, between the continent neourethra and the bladder lumen. Increasing the width of the base of the flap with special attention at trimming unwanted epithelium has minimized this issue.^{4,23} Recently, Canales et al described a modification of Pippi Salle's technique in an attempt to minimize the bladder tissue requirement while achieving excellent continence rates and minimal complications.²⁵ Their concept was that a continent bladder neck procedure with tunnel length and radius halved would increase bladder neck resistance, function as a pop-off mechanism, and perhaps avoid ureteral reimplantation or bladder augmentation. They develop a 1 × 3 cm strip of anterior bladder flap in continuity with the anterior bladder neck. A circumferential ring just inside the bladder neck is de-epithelialized, and the caudal half of the bladder flap is tubularized around an 8 Fr pediatric feeding tube. The mucosal edges of the tube are closed around the bladder neck and sewn together posteriorly, and the tube is tunneled under the trigone, a modification of the Kropp procedure. The cephalad aspect of the flap is narrower and non-tubularized, and sewn in place superior to the trigone as an onlay to the back wall. All patients underwent a continent abdominal stoma and nearly all also underwent enterocystoplasty. With mean follow-up of 31 months, eight or nine reported a dry interval of 3 hours. Although tubularization over an 8 Fr feeding tube provided reliable continence and a pop-off mechanism, this may be difficult to catheterize and irrigate in cases of emergency when the abdominal stoma cannot be catheterized.

Overall, the advantage of the Pippi Salle procedure is the high degree of continence, whereas the disadvantages are the potential for difficulty with catheterization and potential lack of a urethral pop-off valve. In girls, the periurethral sling seems to offer a higher rate of continence, while in boys the Kropp procedure and artificial urinary sphincter have better outcomes. Future modifications may improve the results reported to date.

PERIURETHRAL SLING

An alternative procedure to increase urethral resistance has been the periurethral sling. The use of both autologous and synthetic materials has been reported. Slings may improve continence by compressing the urethra, elevating the bladder outlet into the abdomen, or by providing a stable point against which the urethra is compressed during episodes of increased abdominal pressure.²⁶ Slings are used commonly in women with stress incontinence. In those individuals,

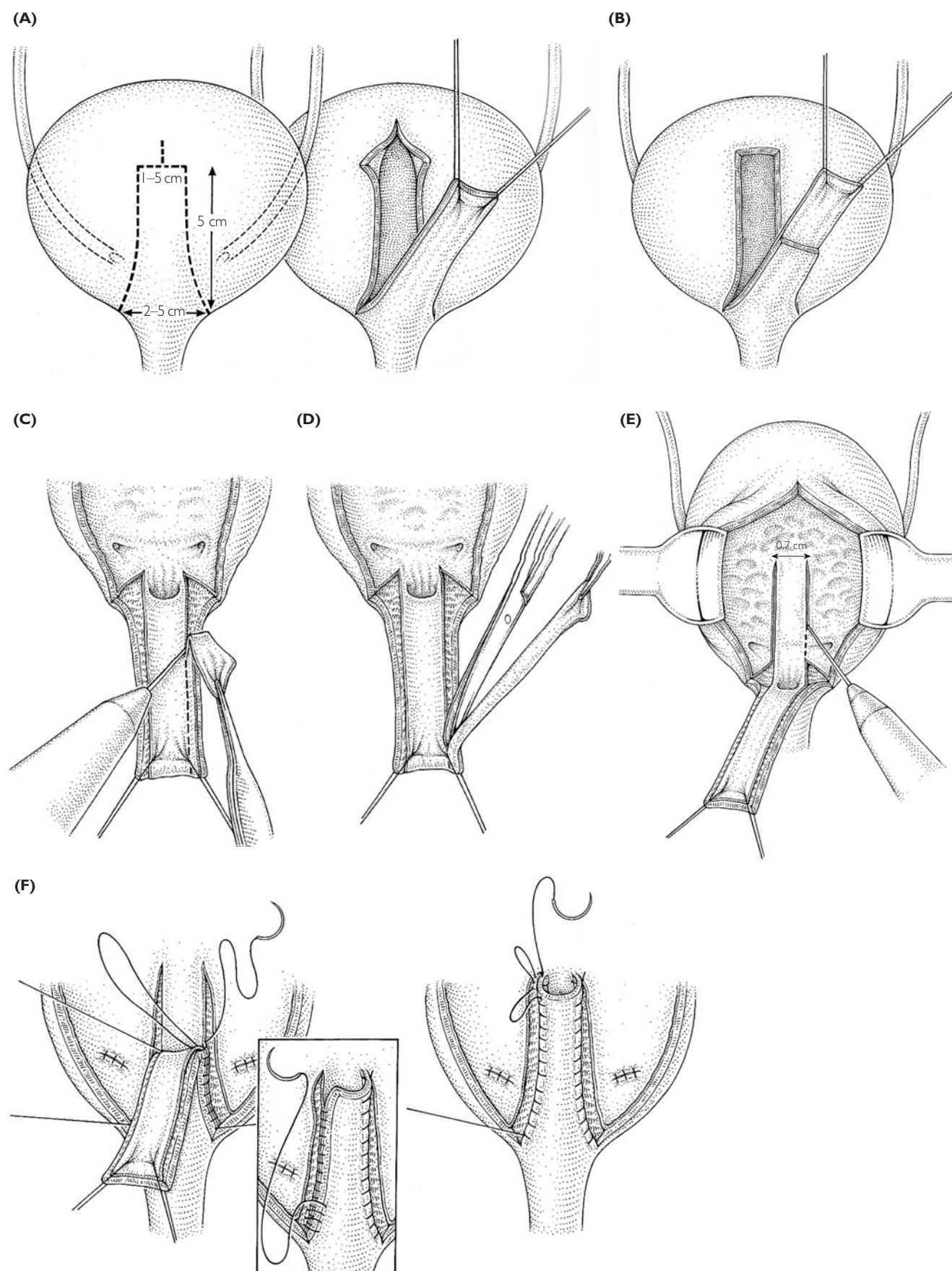


Figure 33.4 (Continued)

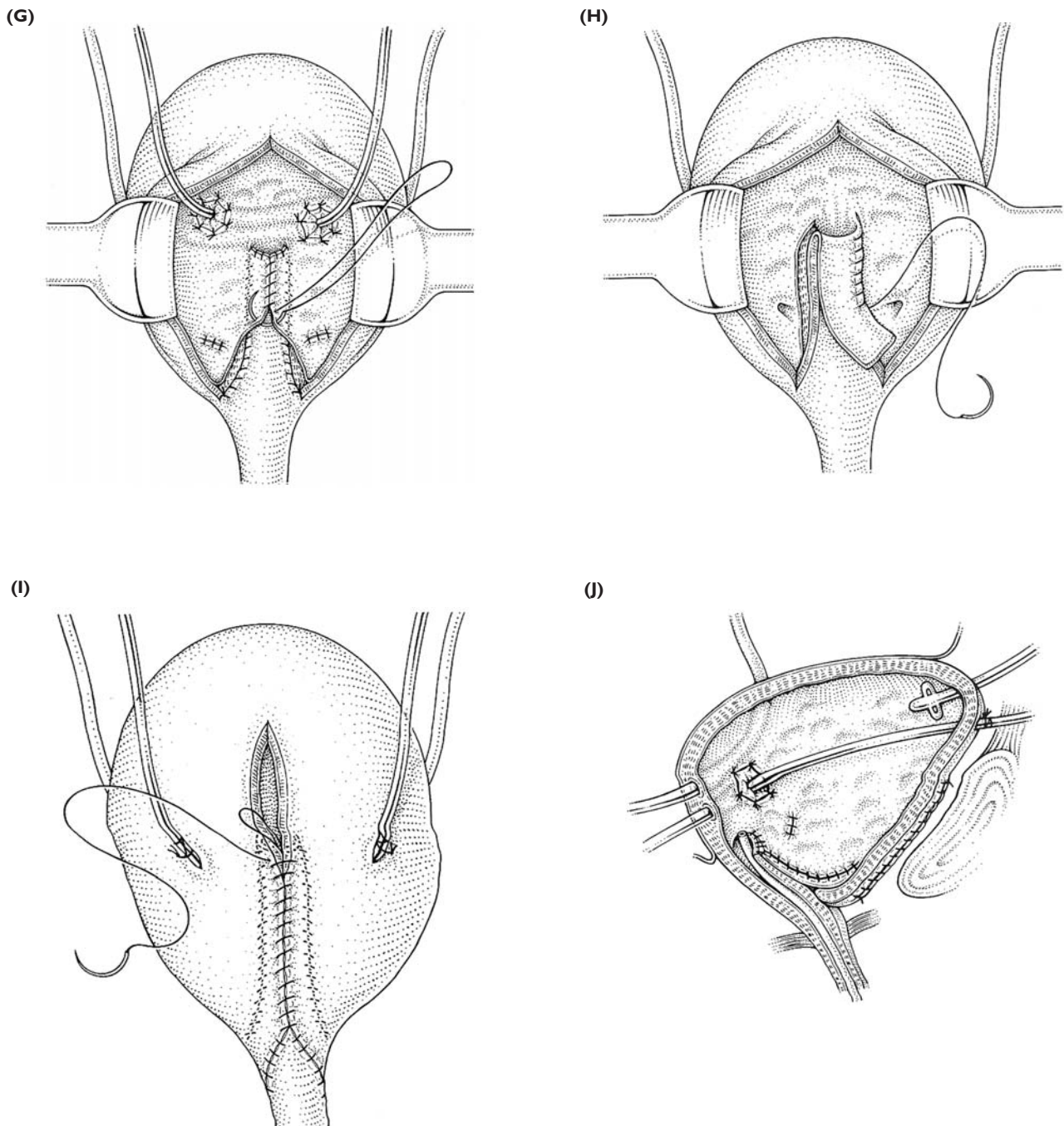


Figure 33.4 Pippi Salle technique. (A) Anterior bladder wall flap is outlined with a wide base to improve the vascular supply. (B) Only the muscular layer of the distal aspect of the flap is incised. Dissection is carried upward in the submucosal plane in order to obtain redundant distal mucosa. (C) Excision of mucosal edges of the flap. (D) Additional removal of the mucosal edge of the muscular part of the flap is done to avoid suture overlapping when it is sutured to the posterior wall. (E) Two parallel incisions, 1 cm apart, are made in the posterior trigonal mucosa to expose the muscle. (F) The anterior bladder flap is dropped onto the incised posterior wall and sutured in two layers, in an onlay fashion. The redundant distal mucosa is folded back over the neourethra and sutured to the lateral mucosa. (G) When reimplantation is necessary, the ureters are reimplanted in a more cephalad position, using the cross-trigonal method. In this case, it is not necessary to fashion the flap with redundant distal mucosa. (H) After reimplantation, mucosal coverage of the neourethra is accomplished, dissecting the posterior mucosa lateral to either side of the posterior bladder incisions. (I) The anterior bladder wall is closed in the midline, causing no tension in the neourethra. If tension is present, it can compromise the vascular supply of the flap leading to ischemia and loss of the flap valve. In most cases, part of the neourethra is kept outside the bladder. (J) Schematic lateral view of the neourethra. The neourethra is situated inside the bladder and has a flap valve mechanism.

the goal is to achieve continence while allowing volitional voiding. In contrast, in patients with a neuropathic bladder, the goal is to create sufficient periurethral compression to achieve continence; since the bladder is abnormal, however, volitional voiding generally will not be possible.

In most centers, rectus fascia or small intestinal submucosa (SIS) is used for the sling. In children the urethra is approached with a retropubic or transperitoneal approach. However, in adolescent and adult women, a transvaginal approach allows exposure of the bladder neck. Most patients with a neuropathic bladder will require an augmentation cystoplasty to increase the bladder volume and success rate of the bladder outlet procedure. Consequently, a midline or transverse lower abdominal incision is made (Figure 33.5). The endopelvic fascia is incised, and the proximal urethra and bladder neck are dissected out. There are large veins adjacent to the proximal urethra and bleeding can be problematic if these are inadvertently transected. It is helpful to open the bladder to allow visualization of the dorsal wall of the bladder neck during the dissection. Using a right angle clamp, a plane at least 3 cm in length is gradually developed between the posterior bladder neck and vagina in girls or rectum in boys. Lottman et al described an alternative approach to the periurethral mobilization that involves a retrovesical approach. The endopelvic fascia is incised, and then the bladder is mobilized dorsally and inferiorly down to the bladder neck.²⁷ The plane is developed between the bladder neck and rectum in boys, and bladder neck and vagina in girls. When the bladder neck is exposed, a right angle clamp is pointed anteriorly on each side of the bladder neck through the incision in the endopelvic fascia. When this plane has been developed, an umbilical tape is passed through the plane until a 3 cm space is made. The advantages of this approach are the lower risk of perforating the posterior bladder neck and a significantly lower risk of bleeding.

In the authors' opinion, simultaneous bladder neck tapering/bladder neck plasty is useful in achieving continence, particularly in males and when the bladder neck is lax. Tapering is achieved by excising a wedge from each side of the bladder neck and proximal urethra. The urethral edges are reapproximated with interrupted 2-0 polyglycolic acid sutures. The bladder neck and proximal urethra are tapered to 12 Fr in adolescents and adults, and 10–12 Fr in prepubertal patients. The distance around the bladder neck should be measured and a piece of rectus fascia is isolated or 4-ply SIS is obtained. The fascia should be 2 cm in width and length should be 3–5 mm less than the urethral circumference. The fascial graft or SIS can be

folded longitudinally on itself, so that it is twice as thick. In addition, it may be wrapped in polyglycolic acid mesh for even more tensile strength. A running 0-polypropylene suture (or other permanent suture) is passed through each end of the graft. The graft is fixed to the urethra proximally and distally on each side of the urethra to avoid curling of the graft. The sling is passed around the bladder neck in girls, or prostatic urethra and bladder neck in boys and the suture ends are criss-crossed anterior to the urethra to provide 360° of circumferential compression (Figure 33.6 and 33.7).²⁸ This bladder neck narrowing is based on the rectus fascial wrap described by Walker et al.^{29,30} A free needle is placed on each of the free suture ends and passed through the abdominal fascia lateral to the rectus muscle and tied together with a surgeon's knot. It is necessary to place significantly more tension around the male urethra than the female urethra to achieve continence. An indwelling catheter or pediatric feeding tube is left through the urethra.

Continence rates have ranged from 40 to 100%, and while fascial slings are highly effective in girls, experience in boys shows more variable but encouraging results^{31–35} (Figure 33.8). Concomitant augmentation cystoplasty has been required in 50–100% of the patients in most series as the vast majority of myelodysplastic patients are unable to void spontaneously and thus depend on intermittent catheterization to empty their bladder.^{31–35} As some myelodysplastic patients can be significantly overweight, harvesting rectus fascia may make the abdominal wall closure more difficult. In these cases, SIS has been shown to produce equivalent rates of continence.³⁶

Placement of a sling is easier in a prepubertal patient, when the bladder is more of an abdominal organ and the bladder neck is easier to dissect out. Finally, the use of an abdominal wall stoma for intermittent catheterization allows the sling tension to be tighter.

Complications may include incontinence, sling erosion, or difficulty with catheterization. Incontinence may be due to altered bladder pressures, inadequate outlet resistance, inadequate bladder drainage during catheterization, infection, loss of the graft, or urethral erosion. Appropriate imaging, urodynamics, and endoscopic evaluation should determine correct management. Significant angulation of the urethra or urethral stricture may cause difficulty catheterizing. In this case, the use of a Coude catheter or sling revision may be indicated. Finally, a rare complication can be ureteral obstruction caused by sling encroachment on ureteral insertion. Ureteroneocystostomy may be necessary to correct this problem.²⁸

As originally described, the periurethral sling provided 180° of compressive force around the urethra,

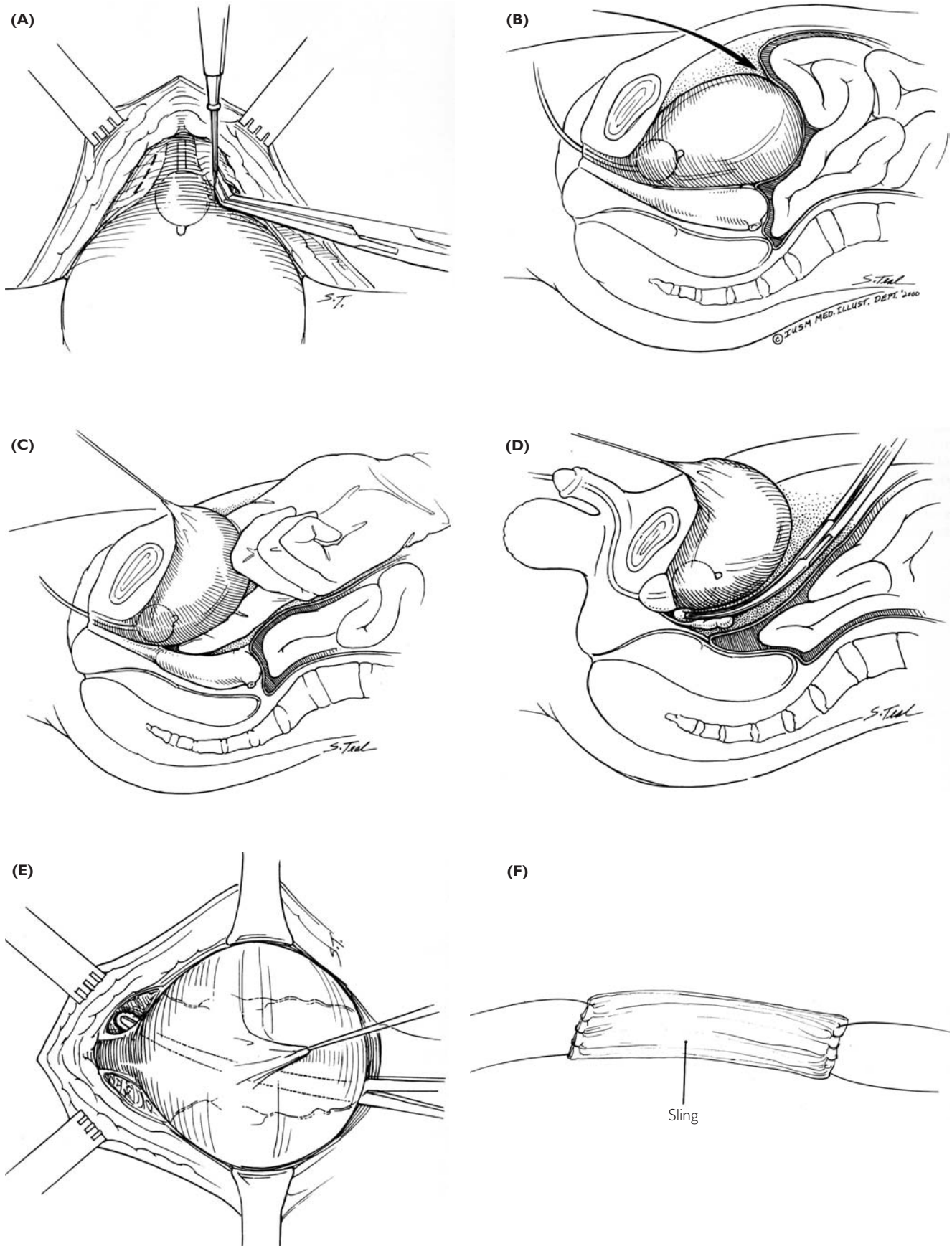


Figure 33.5 (Continued)

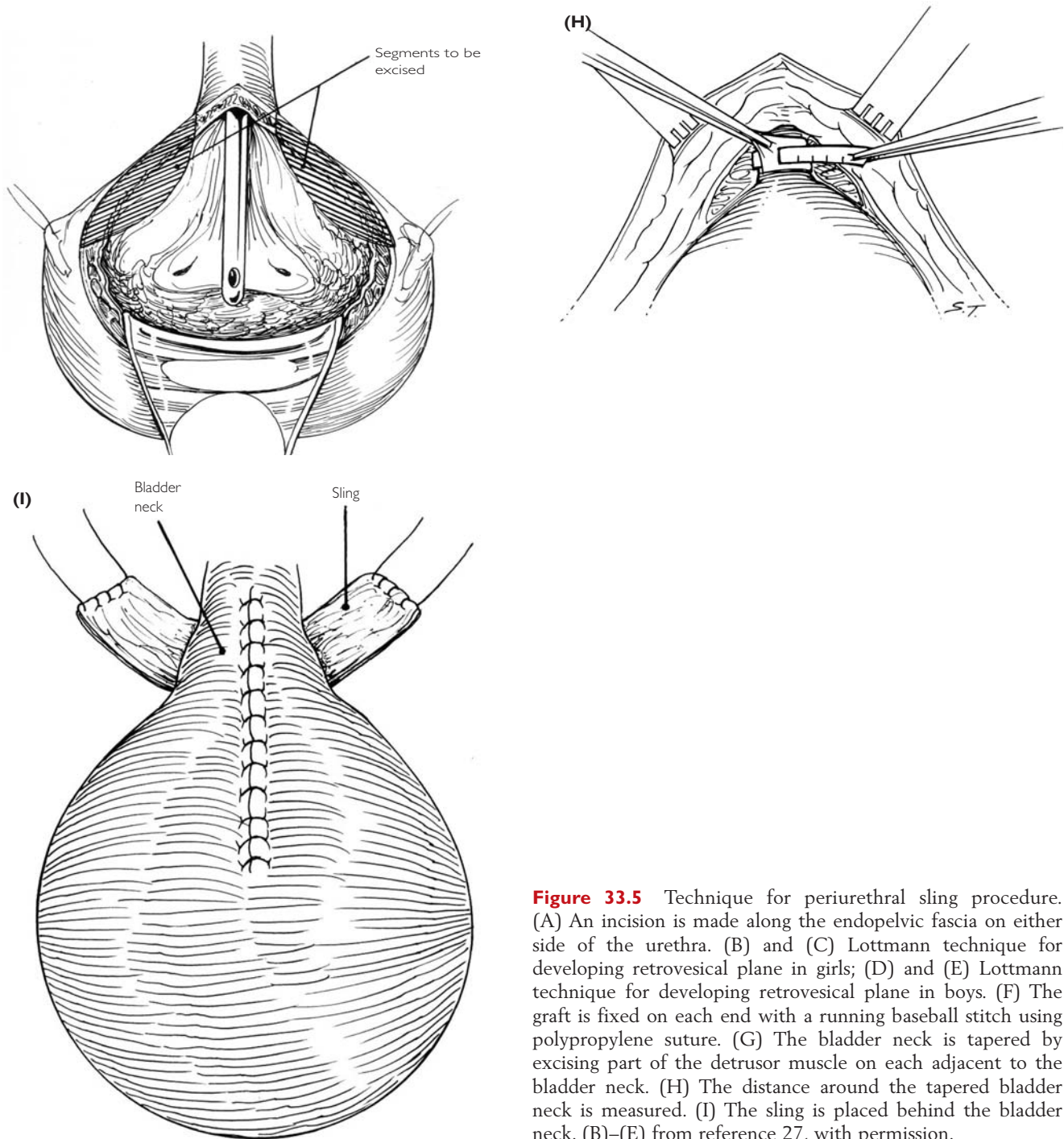


Figure 33.5 Technique for periurethral sling procedure. (A) An incision is made along the endopelvic fascia on either side of the urethra. (B) and (C) Lottmann technique for developing retrovesical plane in girls; (D) and (E) Lottmann technique for developing retrovesical plane in boys. (F) The graft is fixed on each end with a running baseball stitch using polypropylene suture. (G) The bladder neck is tapered by excising part of the detrusor muscle on each adjacent to the bladder neck. (H) The distance around the tapered bladder neck is measured. (I) The sling is placed behind the bladder neck. (B)–(E) from reference 27, with permission.

which theoretically could increase the risk of erosion due to imbalanced compression. An alternative to the above technique is to make a vertical slit in one end of the rectus fascia to facilitate the cinch. In one recent series, this technique provided a continence rate of 60% and the authors speculated that the failures may have been due to fascial wrap deterioration at the site of the slit, limiting compressive forces, or bunching of the wrap as it passed through the slit, decreasing the functional width of increased outlet resistance.³⁰

ARTIFICIAL URINARY SPHINCTER

The AUS is a viable option in the carefully selected neuropathic patient with favorable urodynamic parameters including satisfactory bladder capacity, no detrusor hyperreflexia, and good compliance.³⁷ Some myelodysplastic patients, however, have sphincteric incontinence combined with small bladder capacity and/or poor compliance and therefore often require augmentation cystoplasty. The overall rate of augmentation has been

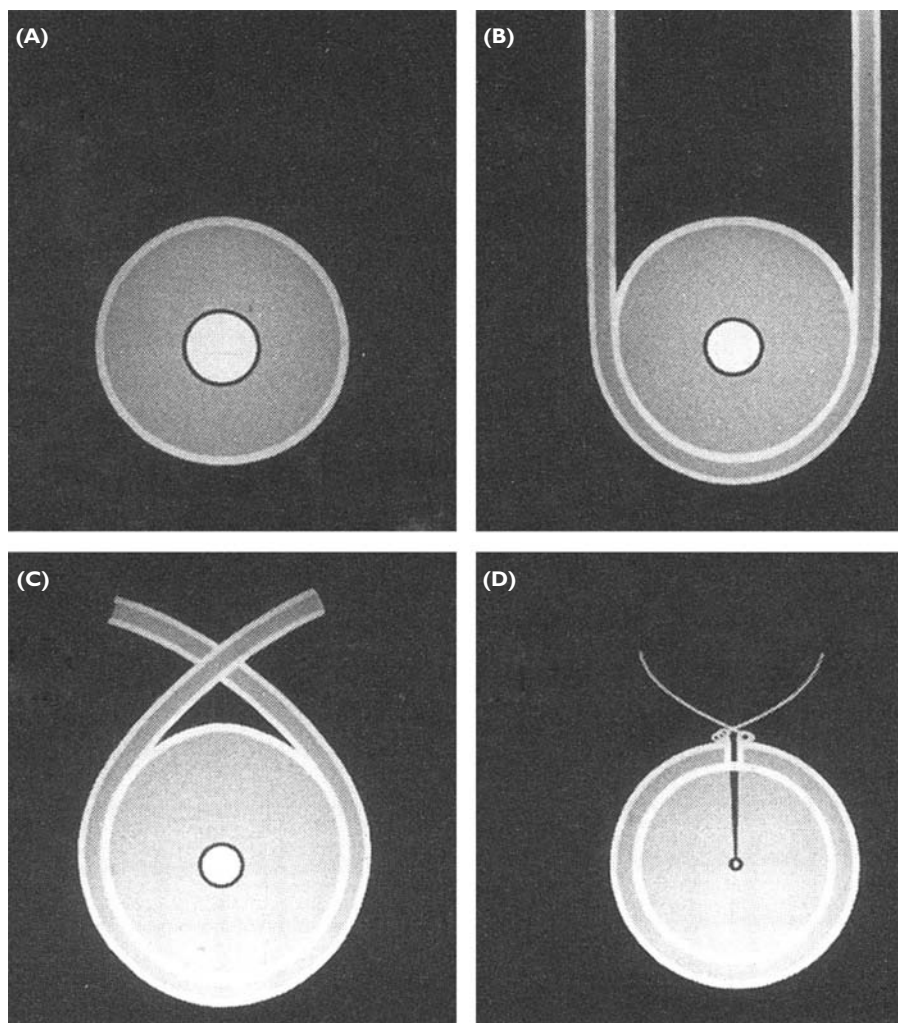


Figure 33.6 Various methods of sling placement. (A) Incompetent urethra. (B) U-shaped position of a periurethral sling. The ends are tied to the pubic symphysis or rectus fascia or are brought together anterior to the rectus fascia. This method provides 270° compression. (C) Technique of criss-crossing ends of the sling, providing 360° compression. (D) Bladder neck is narrowed, and the fascial graft is shortened such that the ends of the graft barely meet anterior to the bladder neck. The graft should be fixed to the bladder neck in two places. The sutures on each end of the graft are criss-crossed to provide 360° bladder neck compression, and the sutures are tied anterior to the rectus fascia.

33–58%.³⁵ The main advantage of the AUS is that it allows for spontaneous bladder emptying. However, as many as 75% of patients need to perform CIC to effect bladder drainage.³⁸ Current refinements in the AMS 800 model have reduced the number of mechanical failures requiring revision.³⁷ The minimum age requirement is 6 years for boys and 8 or 9 years for girls.²⁶

Details of the mechanical action of the AUS are found elsewhere in this textbook. Surgical technique involves placement of an appropriate size cuff around the bladder neck in girls and prepubertal boys, reserving the bulbous urethra for boys with a mature spongiosum.⁴ The reservoir is then placed in the retropubic space and the pump within the labia in females or scrotum in males. The pump should remain deactivated for 6 weeks to allow for healing.

The main complications associated with the AUS are infection and erosion requiring revision. Sphincter infection can be minimized with meticulous surgical technique, sterile preoperative urine, bowel prep, and perioperative intravenous antibiotics. The erosion rate in contemporary studies is between 5 and 15%.³⁵ Risk factors for erosion include previous bladder neck surgery, radiation, and shortened time to activation (less than 6 weeks).⁴ Levesque et al showed that patient age at the time of implantation does not correlate with later need for revision secondary to outgrowing the device. The AUS should never be used to try to increase outlet resistance and expand a small bladder in children with myelodysplasia. In patients who do not undergo an augmentation cystoplasty, close radiographic and urodynamic follow-up is necessary as

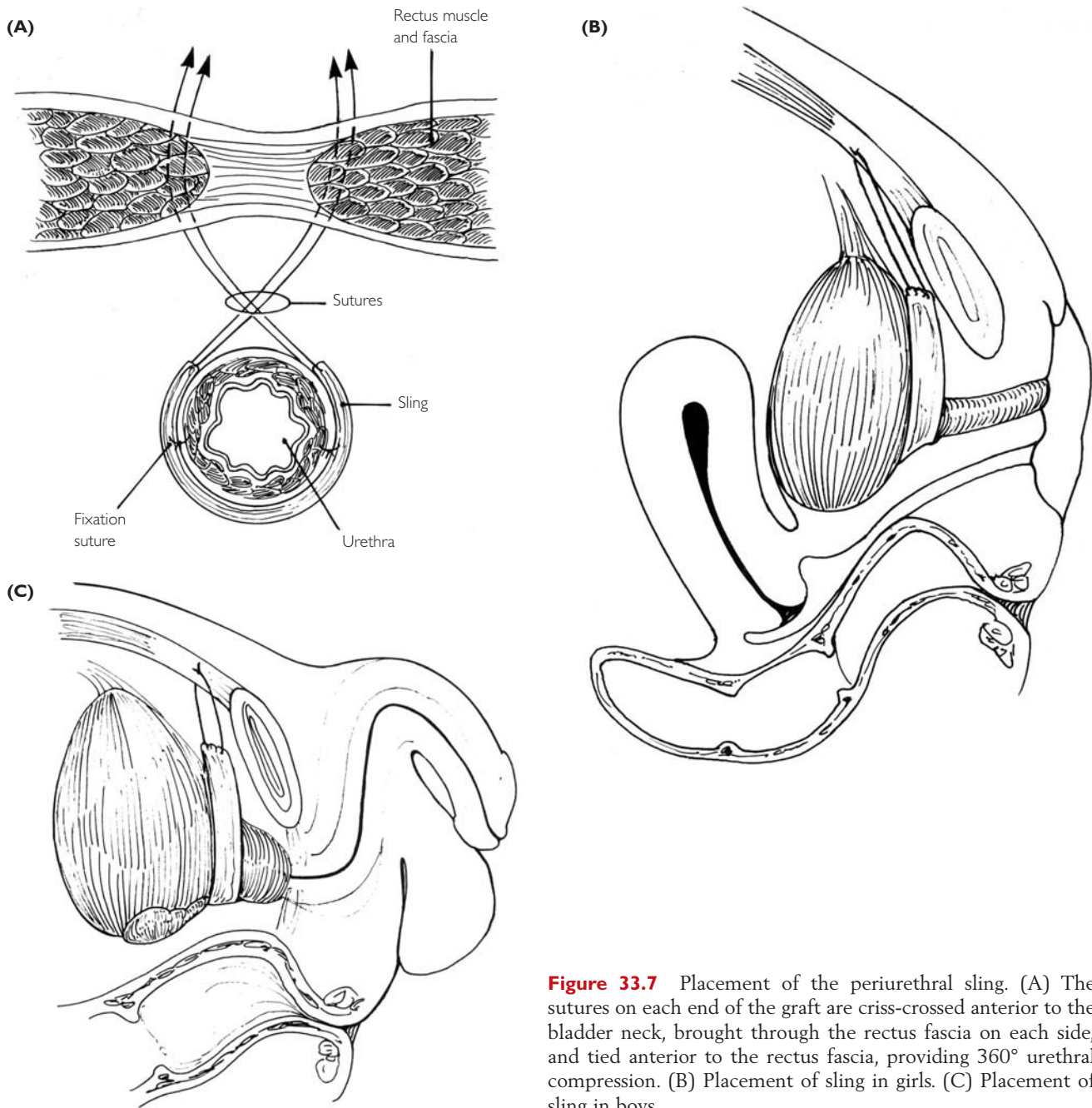


Figure 33.7 Placement of the periurethral sling. (A) The sutures on each end of the graft are criss-crossed anterior to the bladder neck, brought through the rectus fascia on each side, and tied anterior to the rectus fascia, providing 360° urethral compression. (B) Placement of sling in girls. (C) Placement of sling in boys.

new onset hydronephrosis and/or renal failure have occurred in 2–15% of patients resulting from occlusion of the outlet with resultant unmasking of detrusor hyperreflexia, leading to decreased compliance.⁴

BULKING AGENTS

A detailed description of this technique with resultant indications and outcomes is discussed in a later chapter.

BLADDER NECK CLOSURE

In children with intractable urinary incontinence despite previous attempts at bladder neck/sphincter reconstruction, bladder neck closure can be performed as the final surgical procedure to achieve dryness in conjunction with continent urinary diversion and with or without concomitant enterocystoplasty. The patient and their family must understand that the procedure cannot be reversed.

Bladder neck closure requires aggressive mobilization of the bladder away from the urethra once the

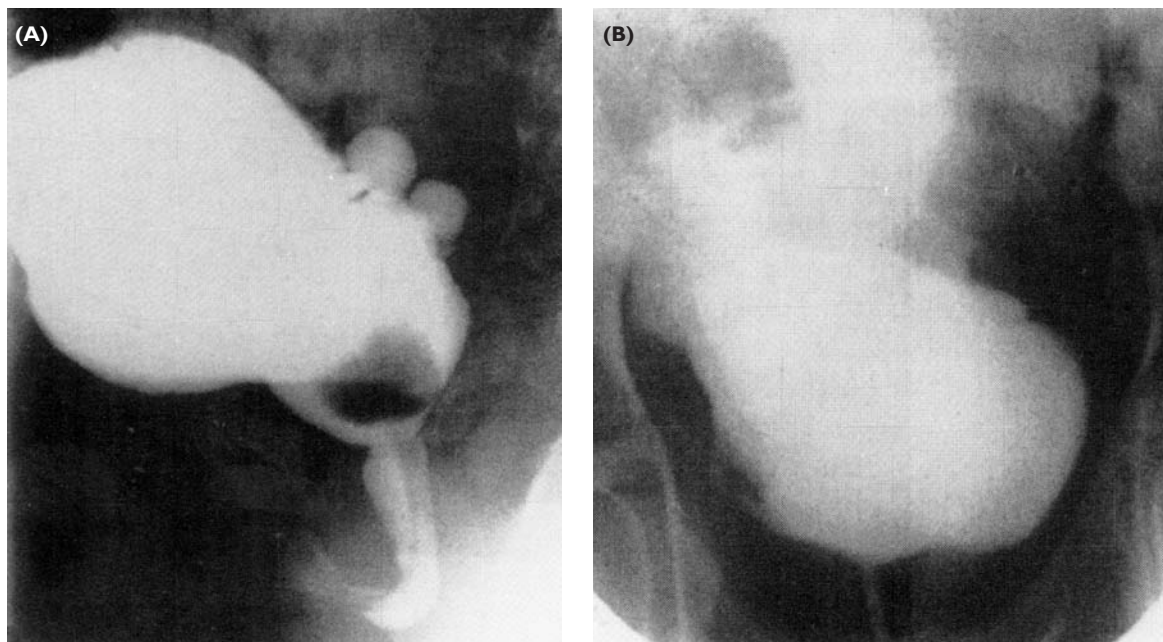


Figure 33.8 The patient was a 10-year-old boy with myelodysplasia. (A) Preoperative cystogram shows the incompetent bladder neck and small trabeculated bladder. The patient underwent enterocystoplasty and periurethral sling. (B) Postoperative cystogram demonstrates elevation of the bladder neck. From reference 31, with permission.

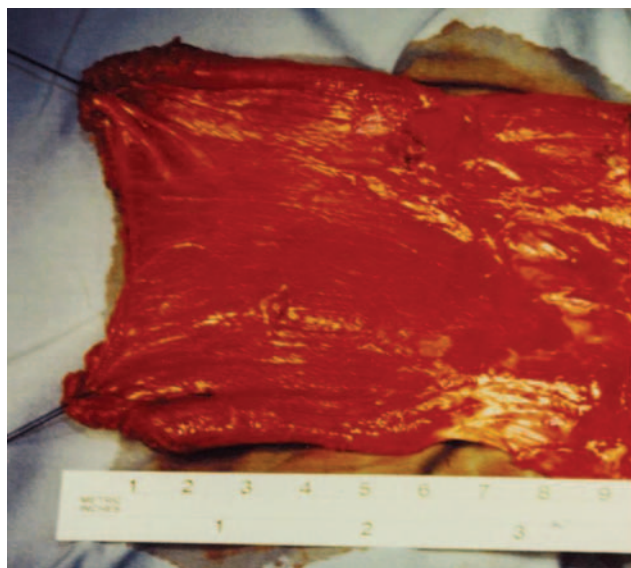


Figure 33.9 Inferior-based rectus muscle flap is used to cover the bladder neck closure to minimize the risk of developing a urethral fistula postoperatively.

bladder neck is divided. The bladder should be closed in multiple layers with non-overlapping suture lines. Interposing omentum between the divided urethra and bladder neck may also be helpful.⁴ The most common complication of bladder neck closure is a distal urethral fistula. In a compilation of three recent series of this procedure involving 40 patients,

four (10%) developed a fistula.^{39–41} The potential for this complication may be minimized by developing an inferior-based rectus muscle flap (Figure 33.9). Long-term follow-up following bladder neck closure revealed a 31% complication rate, with a 15% vesicourethral fistula rate. Risk factors for continued urethral leakage included previous bladder neck surgery, high pressure systems, and patient non-compliance with catheterization.⁴²

CONCLUSION

There are several caveats for the management of sphincteric incompetence in patients with a neuropathic bladder. There is no consensus on the optimal procedure, and multiple patient factors must be considered. Success is more likely if there is a low pressure reservoir at the time of bladder neck repair. CIC and advances in continent stoma reconstruction have played a major role in bladder neck procedures for these patients. Finally, any patient undergoing major reconstruction of the urinary tract requires life-long follow-up.

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34 Augmentation cystoplasty: open and laparoscopic approaches

Raymond R Rackley, Jonathan H Ross, and Joseph Abdelmalak

INTRODUCTION

Augmentation cystoplasty is used as a lower urinary tract reconstructive technique for creating a compliant bladder to protect the upper urinary tract and to provide urinary continence when more conservative management fails. The standard enterocystoplasty involves anastomosing an adequate sized, well vascularized patch of bowel with the urinary bladder. This procedure is classically performed through an open laparotomy incision utilizing various segments of the gastrointestinal system. However, no intestinal segment is a perfect physiologic substitute for a native bladder, and all have the potential for a variety of complications. The choice of the bowel segment is based primarily on the clinical requirements of the patient and secondarily on the preference of the surgeons. Recently, the laparoscopic approach to bladder augmentation has become the primary approach for procedures of augmentation enterocystoplasty. As demonstrated below, the technical steps in performing a laparoscopic bladder augmentation are designed to emulate its open surgical counterpart in every aspect, thereby producing similar functional results with an improved recovery.

INDICATIONS AND PATIENT SELECTION

Augmentation cystoplasty is indicated in patients with chronically contracted or non-compliant bladders caused by conditions such as tuberculosis, schistosomiasis, interstitial cystitis, neurogenic bladder dysfunction (due to spinal cord injuries), multiple sclerosis, myelodysplasia, and detrusor instability. In addition, various congenital conditions may result in a small, poorly compliant bladder that requires augmentation. For patients with physical disabilities who are unable to catheterize themselves via the urethra, a continent catheterizable abdominal stoma may be required in addition to augmentation cystoplasty.

A few contraindications to augmentation cystoplasty include bowel disease (Crohn's disease), abnormal or short bowel (especially after radiotherapy), bladder tumors, and severe radiation cystitis. Significant renal

impairment may be a relative contraindication for augmentation cystoplasty in some patients.

PATIENT PREPARATION

A complete evaluation of the upper and lower urinary tract is required, this typically includes blood work, urinalysis, urine culture (when appropriate), renal ultrasonography, intravenous pyelography, a urodynamic study, and cystourethroscopy.

A clear liquid diet may be given to the patient for 2 days before the operation, and a bowel preparation is performed 1 day prior to the operation. Many patients with neurologic conditions have chronic constipation and may need more time for an adequate bowel preparation. Prophylactic antibiotics for bowel and urinary tract are required, as is antifungal medication when indicated. Barium enema, computed tomography (CT) scan, or colonoscopy is necessary to rule out diverticulosis if the sigmoid colon is to be used.

SURGICAL TECHNIQUE

The patient is placed in the supine or low lithotomy position and pneumatic compression stockings are applied to both legs. After induction with general anesthesia and endotracheal intubation, an oral or nasal gastric tube is inserted; both arms are tucked and protected along the sides. A 20 Fr urethral catheter is placed to provide effective intraoperative urine and pelvic fluid drainage. Depending on whether an open or laparoscopic approach is to be used, a midline incision or a lower abdominal transverse incision, or laparoscopic ports placement is performed.

The surgical technique of enterocystoplasty incorporates the following prerequisites: (1) selection of an optimal segment of bowel based on a broad, well vascularized mesenteric pedicle; (2) isolation of the bowel segment; (3) re-establishment of bowel continuity and closure of the mesenteric defect; (4) detubularization and reconfiguration of the bowel segment without peritoneal soiling of bowel contents; (5) bladder mobilization

with formation of an adequate sized cystotomy; (6) creation of a tension-free, watertight, full-thickness, circumferential anastomosis of the bowel to the bladder; and (7) confirmation of adequate postoperative urinary drainage.

BLADDER MOBILIZATION AND CYSTOTOMY

The bladder is distended with fluid through the urethral catheter. The loose areolar tissue surrounding the bladder is bluntly dissected to expose the anterior bladder neck and perivesical spaces. While many different cystotomy incisions have been described, we prefer a transverse wide 'U' shaped cystotomy incision with the apex approaching the anterior bladder neck and the base extending posteriorly past the mid-coronal plane of the bladder dome. This type of cystotomy ensures a large disruption of the bladder musculature to increase the linear length of the bladder wall to bowel anastomosis. Other cystotomy options include a midline sagittal or mid-transverse cystotomy.

BOWEL SELECTION AND MOBILIZATION

Various segments of bowel can be used for augmentation cystoplasty depending on the clinical requirements of the patient and the preference of the surgeons. A length of 20 cm is usually desirable to attain an adequate augmented bladder capacity.

In ileocystoplasty, the initial step is identification of the ileocecal junction. Then a 20 cm segment of ileum at least 20 cm proximal to the ileocecal junction is required. The sigmoid colon is chosen if the patients can easily perform intermittent catheterization via the urethra and a continent catheterizable stoma formation is not required. In addition, many patients may have a redundant sigmoid segment secondary to neurogenic bowel dysfunction.

In ileocecocystoplasty, the cecum and ascending colon are used for the bladder augmentation, and 12 cm of terminal ileum are used to create the catheterizable conduit and stoma at the umbilicus. The peritoneum lateral to the cecum and ascending colon, and the peritoneum of the terminal aspect of the Z line are incised, and the entire right colon and terminal ileum are mobilized for harvesting.

In open approaches for augmentation cystoplasty, the preselected loop of bowel is isolated with care taken to prevent any twisting of the mesenteric pedicle

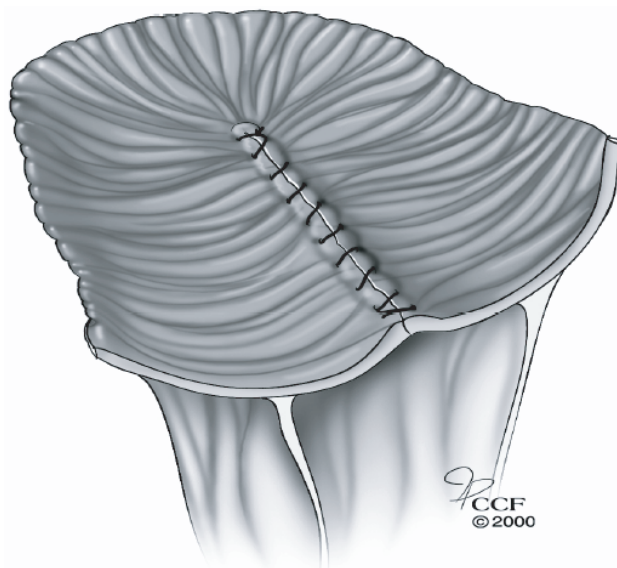


Figure 34.1 Detubularization and reconfiguration of a 'U' shaped plate of bowel. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

and to ensure proper proximal–distal orientation of the loop. The excluded bowel segment is draped in moist warm sponges and then irrigated thoroughly with normal saline until the returning irrigation fluid is clear. The antimesenteric border of the bowel is incised using electrocautery. For the small bowel or sigmoid, a 'U' shaped plate is created by a side-to-side anastomosis with 2-0 Vicryl sutures (Figure 34.1). Bowel continuity is re-established using a gastrointestinal anastomosis (GIA) stapling device and the mesenteric window is closed.

For patients requiring a catheterizable stoma, the right colon and the terminal ileum are extracorporealized through the laparoscopic port site for reconstructive purposes. Following detubularization of the cecum and proximal colon, an appendectomy is performed. The terminal ileum is narrowed over an 18Fr red rubber catheter using a GIA stapler, and the ileocecal junction is imbricated and intussuscepted using 2-0 braided polyester sutures to augment the continence mechanism of the ileocecal valve (Figure 34.2).

A circumferential, continuous, full-thickness, single-layer anastomosis of the bowel to the bladder is performed using 2-0 braided absorbable sutures (Figure 34.3). At the completion of the anastomosis, the bladder is distended to confirm a watertight anastomosis. A drain is inserted into the pelvic cavity. Bladder drainage is maintained with a 24 Fr urethral catheter in women; a suprapubic tube may be an additional option in men who require a smaller urethral catheter.

In patients who require a catheterizable stoma, the previously refashioned ileal segment is delivered to

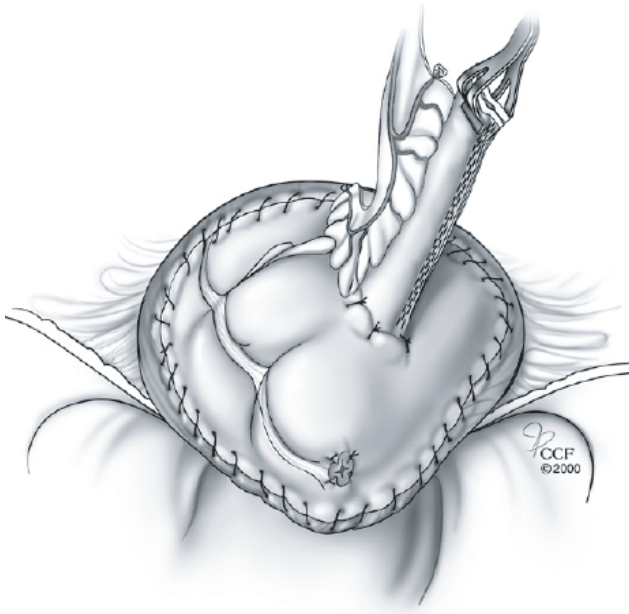


Figure 34.2 The terminal ileum is narrowed over an 18Fr red rubber catheter using a stapler and the ileocecal junction is imbricated and intussuscepted to augment the continence mechanism of the ileocecal valve. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.



Figure 34.3 Performing the circumferential, continuous, full-thickness, single-layer anastomosis of the bowel to the bladder. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

the umbilicus and secured to the anterior rectus fascia and skin at the level of the umbilicus using 4-0 chromic sutures. A 16Fr catheter is placed through the stoma and into the bladder to optimize the bladder drainage and the healing of the newly created catheterizable segment during the early postoperative period.

In gastrocystoplasty, either the antrum or a wedge of stomach from the greater curvature can be used. The

pyloric antrum of the stomach is excised and is brought down to the pelvis on a pedicle of omentum, along with its blood supply from the left gastroepiploic artery (Figure 34.4).

When using a wedge of stomach from the greater curvature (Figure 34.5), the greater omentum is incised along the edge of the greater curvature of the stomach. The gastric wedge is resected using a stapling device. The gastric wedge, with its blood supply from right gastroepiploic artery, is retroperitonealized through the mesentery of the transverse colon and small bowel, and brought down into the pelvis. The staple line of the stomach is then removed and the incision is closed using a two-layer closure.

LAPAROSCOPIC AUGMENTATION CYSTOPLASTY

An incision is made at the superior umbilical crease and a 10 mm port for the camera is introduced under direct vision into the peritoneal cavity. A 10 mm, 0° or 30° laparoscope is introduced and the subsequent reusable ports are introduced under visual guidance. Ports (10 or 5 mm) are inserted bilaterally at the lateral borders of the rectus muscle at the level of the umbilicus (Figure 34.6). Most of the operative suturing takes place via the two paraumbilical ports. The 10 mm port facilitates the introduction of sutures by the primary surgeon. An additional 5 mm port is inserted at the level of the left anterior superior iliac spine. Other ports may be placed depending on the bowel mobilization required and the surgeon's preference.

LAPAROSCOPIC BLADDER MOBILIZATION AND CYSTOTOMY

Placing the patient in the Trendelenburg position aids in displacement of bowel loops from the pelvic cavity and facilitates the subsequent steps of the procedure. The bladder is distended with saline through the urethral catheter. The peritoneum overlying the bladder is incised at the medial border of the left medial umbilical ligament and extended to the right in a linear fashion to the right medial umbilical ligament. The median umbilical ligament is taken down during the procedure using the electrocautery scissors. If needed, the lateral peritoneum incisions are extended down along the medial umbilical ligaments to increase exposure. The loose areolar tissue surrounding the bladder is bluntly dissected for exposure of the anterior bladder neck and perivesical spaces. A large

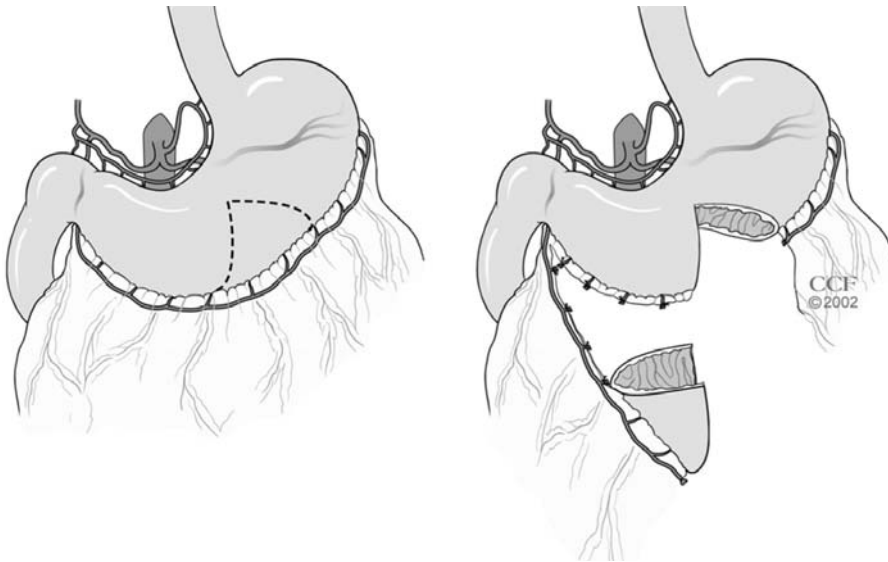


Figure 34.4 Excising the pyloric antrum of the stomach on a pedicle of omentum with its blood supply. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

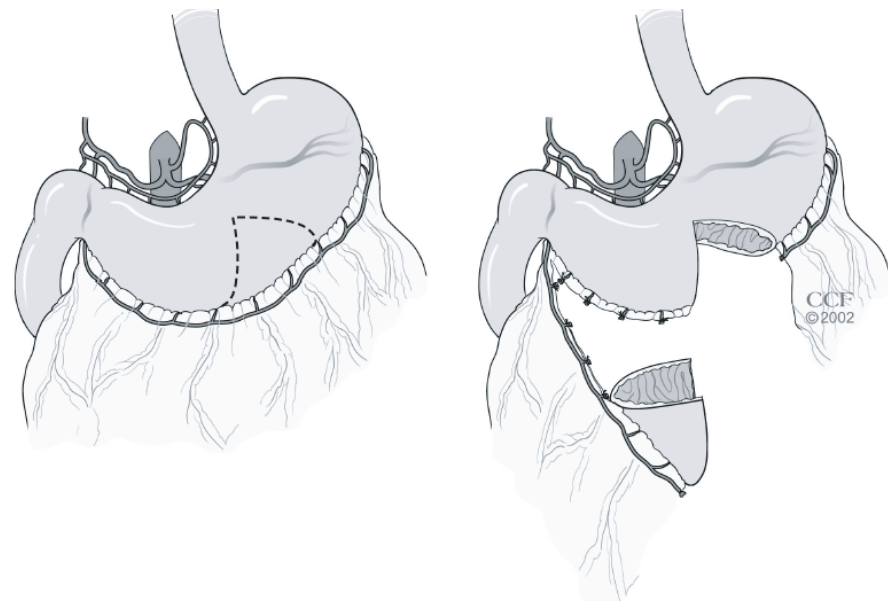


Figure 34.5 Incising the greater omentum along the edge of the greater curvature of the stomach. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

cystotomy is created by making an anterior bladder wall flap through a curvilinear incision that positions the apex approaching the bladder neck and the base extending posteriorly past the mid-coronal plane of the bladder dome. This type of cystotomy ensures a large dysfunctional disruption of the bladder musculature to increase the linear length of bladder wall for bowel anastomosis. It is most useful in cases where the uterus is present and potentially prevents an adequate cystotomy incision. Furthermore, adequate exposure for enterovesical anastomosis in all of the procedures described previously is preserved by avoiding closure of a deep posterior bladder wall incision in the pelvis that will be obscured by bowel and the isolated bowel segment to be used for the augmentation.

LAPAROSCOPIC BOWEL SELECTION AND MOBILIZATION

As in open enterocystoplasty, various segments of bowel can be used for the procedure depending on the clinical requirements of the patient. In laparoscopic ileocystoplasty, after identification of the ileocecal junction, a 20 cm segment of ileum at least 20 cm proximal to the ileocecal junction is identified. A 5 mm laparoscope may be introduced through the lower left port to transilluminate the mesentery and to identify its vascular pedicle. The mesentery adjacent to the proximal and distal ends of the selected bowel loop is scored with laparoscopic electrocautery scissors for subsequent extracorporeal identification.

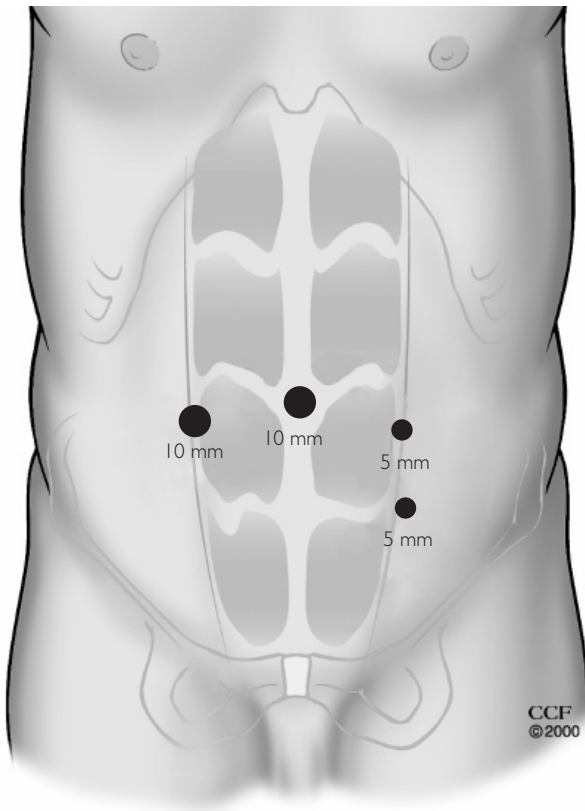


Figure 34.6 Options for selection of port sizes and location in laparoscopic augmentation cystoplasty procedures. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

In laparoscopic sigmoidocystoplasty, a loop of sigmoid colon is selected using similar techniques. A 10 mm port is placed medial to the level of the right anterior iliac spine and facilitates sigmoid mobilization for extracorporeal manipulation via extension of the lower left abdominal port defect.

The right colon and terminal ileum are selected in patients who, in addition to bladder augmentation, require a continent catheterizable abdominal stoma using the same traditional open surgical techniques. The entire right colon and terminal ileum are mobilized for extracorporeal manipulation via the extended incision of the umbilical port. Ensuring a low position of the patient's thighs with low lithotomy enables proper manipulation of the laparoscopic instruments through the lower abdominal ports for mobilization of the right colonic flexure.

LAPAROSCOPIC EXCLUSION AND REANASTOMOSIS OF THE BOWEL

After bowel selection and mobilization the pneumoperitoneum is desufflated and the umbilical port

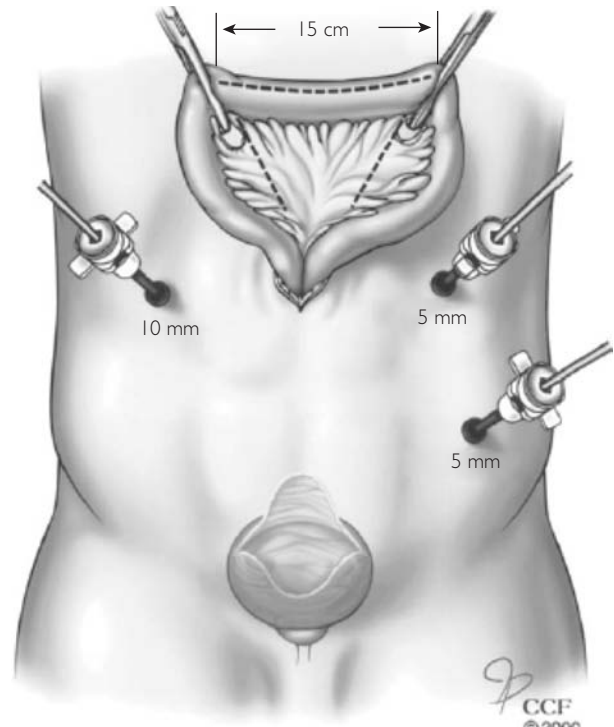


Figure 34.7 Extracorporeal isolation and manipulation of the small bowel via the umbilical port site. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

is removed. The umbilical incision is enlarged circum-umbilically and extended inferiorly in obese cases for an additional 2 cm. The preselected loop of bowel is delivered extracorporeally through this incision (Figure 34.7). Care is taken to prevent any twisting of the mesenteric pedicle and to ensure proper proximal-distal orientation of the loop. Using traditional open surgical techniques, the 20 cm bowel segment with its pedicle is divided between bowel clamps and isolated as performed in ileocystoplasty. Bowel continuity is re-established using traditional open techniques and the mesenteric window is closed. The bowel anastomosis is performed cephalad to the excluded segment of bowel and the reanastomosed bowel is returned to the abdominal cavity before any further manipulations. This step reduces the potential need to enlarge the circumumbilical incision for reintroduction of an edematous combination of both the bowel reanastomosis and the reconfigured bowel segment for augmentation.

REFASHIONING OF THE ISOLATED BOWEL SEGMENT

The excluded bowel segment is draped in moist warm sponges and then irrigated thoroughly until the

returning irrigation fluid is clear. The antimesenteric border of the bowel is incised using electrocautery. For the small bowel or sigmoid, a 'U' shaped plate is created by a side-to-side anastomosis with 2-0 braided absorbable suture as previously shown (Figure 34.1). After the isolated bowel segment for augmentation is reintroduced into the peritoneal cavity, the ports are replaced to re-establish the pneumoperitoneum. In laparoscopic augmentation cystoplasty, reintroducing a disposable 10 mm, blunt-tip port with a fascial retention balloon and foam cuff to minimize gas leakage is advantageous.

In sigmoidocystoplasty, the extended lower left abdominal port incision is reduced to accommodate a 10 mm port. The pneumoperitoneum is then re-established and the laparoscope inserted. The isolated bowel segment is oriented appropriately and inspected to exclude torsion of the pedicle.

For patients requiring a catheterizable stoma, the right colon and terminal ileum are utilized. Following detubularization of the cecum and proximal colon, an appendectomy is performed. The terminal ileum is narrowed over an 18Fr red rubber catheter using a gastrointestinal stapling device, and the ileocecal junction is imbricated and intussuscepted to augment the continence mechanism of the ileocecal valve using 2-0 braided polyester sutures (Figure 34.8). Orientation sutures are placed at the cephalic end and the caudal end of the bowel patch to facilitate intracorporeal laparoscopic identification and manipulation. The 18Fr red rubber catheter is secured to the terminal end of the catheterizable segment of ileum with a 2-0 silk suture for atraumatic intracorporeal manipulation and for delivering this terminal segment to the umbilicus for stoma maturation at the end of the procedure. The isolated bowel patch is then returned to the abdominal cavity, and the infraumbilical incision is closed over a 10mm blunt-tip port with a fascial retention balloon and foam cuff to minimize gas leakage for the remainder of the operation. After the pneumoperitoneum is re-established and the laparoscope inserted, the isolated bowel segment is oriented appropriately and inspected to rule out torsion of the pedicle.

Exclusion of the bowel segment and subsequent restoration of bowel continuity can be performed intracorporeally using endoscopic staplers. We prefer to perform these manipulations extracorporeally by delivering the bowel outside the abdomen through the umbilical or lower abdominal port site for several reasons. The bowel segment can be measured precisely and incision of the mesentery may be performed after ensuring good vascularity. The re-anastomosis of the



Figure 34.8 View of the completed laparoscopic bowel to bladder anastomosis in preparation for maturation of the catheterizable stoma to the umbilicus. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

bowel can be performed meticulously using open surgical techniques with increased confidence. The irrigation of the excluded loop can be performed without any peritoneal spillage, thereby eliminating the potential for subsequent pelvic abscess formation. The detubularization and desired modification of the isolated loop can be performed expeditiously by traditional open suturing. If the mesenteric length allows the segment to be delivered outside the anterior abdominal wall comfortably without evidence of bowel ischemia, it is also likely to reach the bladder without tension. The extracorporeal approach allows considerable savings in overall operative time and cost.

LAPAROSCOPIC ENTEROVESICAL ANASTOMOSIS

Although different approaches can be used for intracorporeal suturing of the bowel segment to the bladder, we prefer to begin by running the preplaced suture on the 'posterior' wall of the re-configured bowel patch to the apical aspect of the bladder flap in

a medial to lateral direction on each side. Completion of the 'posterior' wall of the reconfigured bowel segment from an intravesical approach beginning medially and finishing laterally facilitates the best exposure to ensure a watertight anastomosis. If one attempts to complete the 'anterior' wall of the reconfigured bowel patch to the bladder first, visualization for suturing the 'posterior' wall anastomosis to the bladder may be difficult owing to the constraints of the pelvic anatomy.

To complete a circumferential, continuous, full-thickness, single-layer anastomosis of the bowel to the bladder, we run the preplaced sutures of the 'anterior' wall of the reconfigured bowel patch and additional sutures as required. The entire suturing is performed exclusively using free hand laparoscopic suturing and intracorporeal knot tying techniques. A 5 mm needle holder is used to perform the anastomosis. An assistant follows the sutures with a 5 mm grasper. At the completion of the anastomosis, the bladder is distended to confirm that it is watertight. A drain is inserted into the pelvic cavity through a lower lateral 5 or 10 mm port site. In female patients, bladder drainage is maintained with a 20–24F urethral catheter. Because a smaller urethral catheter is preferred for postoperative drainage in males, a suprapubic tube is placed through the bladder wall and externalized via the remaining lower port site. The umbilical port and any remaining 10 mm ports are closed in layers.

In patients who require a catheterizable stoma, the previously refashioned ileal segment is located and the attached red rubber catheter is grasped with an endo-clamp via the umbilical port site (Figure 34.8). After the pneumoperitoneum is decompressed, the terminal end of the ileal segment is delivered to the umbilicus and secured to the anterior rectus fascia and skin at the level of the umbilicus. A Y-V flap maturation of the stoma to the skin of the umbilicus is performed using 4-0 chromic sutures. In obese patients, use of the umbilicus as the site of stoma formation decreases

the amount of ileum needed to mature the stoma to the skin. A 16 Fr catheter is placed through the stoma and into the bladder to optimize bladder drainage and the healing of the newly created catheterizable segment in the early postoperative period.

POSTOPERATIVE MANAGEMENT

The nasal or oral gastric decompression tube is typically removed before extubation. The pelvic drain is removed when the drainage is less than 25 ml or fluid chemistries suggest peritoneal fluid. Discharge criteria are met when the patient is afebrile and able to complete three consecutive meals without abdominal distention or symptoms of nausea and vomiting; the first meal is usually started on the first postoperative day. Patients are discharged with the indwelling urethral catheter used for bladder drainage and daily bladder irrigation with 100 ml of sterile saline. Low dose antibiotics for prophylaxis are continued during the first 3 postoperative weeks. At that time, the urinary catheter is removed and intermittent catheterization is initiated. For patients who have an indwelling catheter via the umbilical stoma, the catheter is usually capped at the time of hospital discharge, but may be used to flush the augmented bladder at the time of the daily bladder irrigation.

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35 Bladder neck closure: male and female

Ginger Isom-Batz and Philippe E Zimmern

INTRODUCTION

Bladder neck closure (BNC) is an uncommon procedure which was initially fraught with a high failure rate, but patient selection and technical refinements have allowed some authors to achieve a high success rate.¹ This chapter focuses on the techniques of both abdominal and vaginal bladder neck closure in the female and abdominal bladder neck closure in the male with emphasis on the technical principles necessary to achieve both successful and durable results.

INDICATIONS FOR SURGERY

Female

The indications for bladder neck closure in the non-neurogenic patient are traumatic urethral destruction, severe intrinsic sphincteric deficiency that is not amenable to or has failed conventional treatment, and urethrovaginal fistula failing prior attempts at repair. Patients suffering from neurogenic incontinence often have intractable leakage from extensive urethral damage due to the long-term effects of an indwelling urethral catheter (Figure 35.1). A common indication is the patient with advanced multiple sclerosis and neurogenic detrusor overactivity resulting in repeated catheter extrusion and gradual destruction of the urethra to the point of ending with a patulous, gaping open bladder neck. Though control of incontinence has been achieved by some using a tight pubovaginal sling,² many patients with urethral destruction or reduced urethral length are not suitable candidates for this procedure.

Male

The role of BNC in the male with benign disease resides in the management of refractory urethrocutaneous or urethrorectal fistula and in cases of severe neurogenic or postoperative incontinence (with low outlet resistance) when an artificial urinary sphincter is not an option. It may also be used in the treatment of recalcitrant urethral strictures when reconstruction is impossible or undesired.

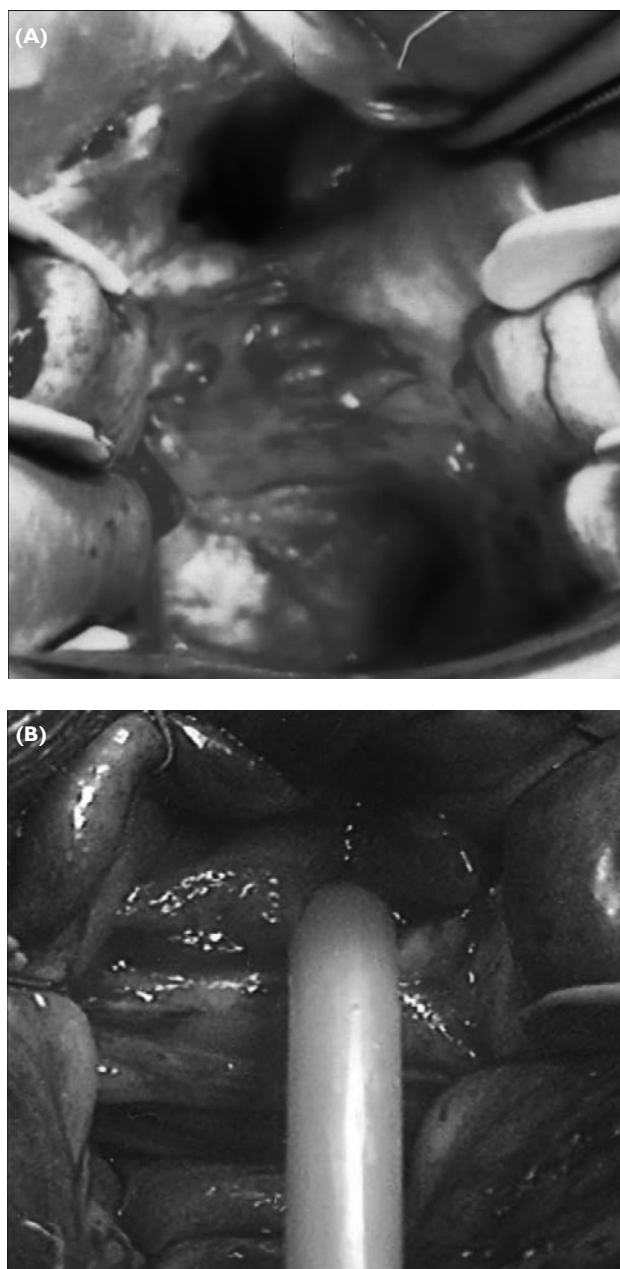


Figure 35.1 Two examples of destroyed urethra. (A) Gaping open bladder neck. (B) Urethral wall remnants around the Foley catheter. In both patients with advanced multiple sclerosis, catheters of increasing size were used for control of their incontinence.

BNC may be considered in conjunction with salvage prostatectomy for locally recurrent prostate

adenocarcinoma after radiation therapy. Complications encountered after salvage cryotherapy, such as urinary incontinence, puboprostatic fistula, and intractable perineal pain, may be amenable to prostatectomy with BNC as well. Many of these patients will have more than one of these complications and may have already undergone multiple less definitive surgeries to alleviate their symptoms with short-lived success.³

SURGICAL TECHNIQUE

The goals of the surgery, for both males and females, are wide mobilization of the bladder neck to allow for tension-free, multilayer closure of the outlet without overlapping suture lines thereby reducing the opportunity for fistula, interposition of vascularized tissue between the vesical outlet and urethral stump or vagina, and adequate postoperative bladder drainage with a large-bore catheter.⁴

Vaginal approach (female)

This approach is preferred in the female with no history of pelvic radiation who wishes to avoid and does not need an abdominal procedure, and who accepts the risks of prolonged suprapubic tube drainage such as infection, stones, and neoplasm. The advantage of a vaginal dissection is less morbidity with a shorter time to convalescence for the patient. The disadvantages are that it is a technically more challenging procedure with the possibility for significant retropubic bleeding and secondary vesicovaginal fistula formation. Tissue interposition with a Martius flap is generally considered to minimize the risk of fistula formation. Another problem with this approach is that some patients may have lower extremity contractures which may limit vaginal exposure.

Preoperatively, vaginal douching and an enema should be performed, and the patient should receive broad spectrum antibiotic therapy and deep venous thrombosis prophylaxis. Use of a headlight is recommended. The steps of the procedure are outlined below.

- Positioning: high lithotomy with careful attention to padding of all pressure points
- Vaginal retractors: Lone Star ring retractor (Lone Star Medical Products, Houston, TX) and a weighted vaginal speculum
- Suprapubic tube placement: a standard puncture kit may be used; however, because many patients have a small contracted bladder and a patulous or destroyed urethra which leaks easily, we prefer to use the Lowsley retractor
 - Place patient in deep Trendelenburg position to displace bowel contents
 - Make a short 1 inch midline suprapubic incision and expose rectus fascia above the symphysis pubis
 - Introduce the curved retractor through the urethra and direct its tip to the dome of the bladder, about 1–2 cm above the symphysis pubis
 - Make a small incision over the tip of the Lowsley, which can be palpated beneath the fascia
 - Push the tip of the retractor out through the fascial incision, then open the jaws and grasp a large size (20 or 22 Fr) Foley catheter between the open jaws
 - Pull the catheter back into the bladder and verify its intravesical position with irrigation or with cystoscopy before inflating the balloon
 - Pull the balloon back up on traction at the dome of the bladder to avoid secondary bleeding at the point of the bladder puncture
- Vaginal wall incision (recommend marking with a waterproof surgical ink pen)
 - Mark an inverted ‘U’ shape incision, extending around the urethral meatus (Figure 35.2)
 - Consider injecting a dilute solution of vasopressin 60 U/100 ml or normal saline into the periurethral tissue and anterior vaginal wall to facilitate dissection and reduce local bleeding
- Vaginal flap elevation
 - After a circumscribing incision has been made around the urethral meatus, a broad-based inverted ‘U’ shaped vaginal flap is elevated (Figure 35.3) The flap not only aids in the exposure of the bladder neck but also later serves as an advancement flap to close over the closed vesical outlet and interposed labial fat pad. When in the correct plane, the vaginal wall exhibits a distinctly recognizable white glistening surface. When the dissection is carried out too deep and into the venous sinuses of the bladder wall, significant bleeding may be encountered
- Martius flap dissection
 - This is a strongly recommended step to reduce the risk of vesicovaginal fistula. We suggest preparing the labial fat pad at this point due to the chance of heavy bleeding during the retropubic dissection of the bladder neck and the subsequent need for a speedy closure
 - This step relies on a well vascularized fibrofatty labial pad (from the labia majora) that is based

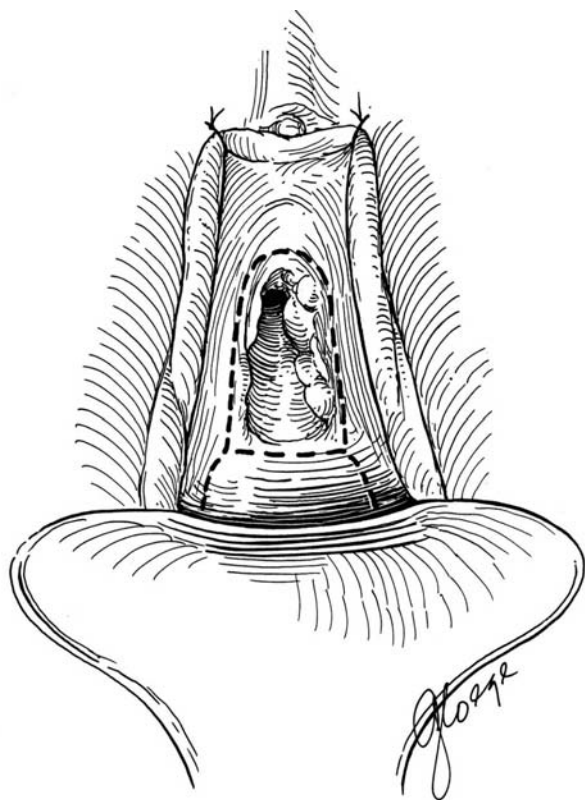


Figure 35.2 The incision circumscribes the outlet and extends towards the anterior vaginal wall with an inverted 'U' shape incision which allows for mobilization of a wide anterior vaginal wall flap away from the bladder base. This flap will be advanced at the end of the procedure to cover the closed outlet and the interposed tissue.

posteriorly on a labial branch of the internal pudendal artery (Figure 35.4)

- Detach bladder neck
 - Free the urethral remnant and/or bladder neck from its lateral and anterior fascial attachments. This must be done completely to achieve a tension-free closure. There is a risk of brisk retropubic bleeding during this difficult part of the dissection
 - The pubourethral ligaments are sharply dissected above the urethral remnant and just beneath the pubic symphysis on the midline
 - After entering the retropubic space, blunt dissection is used to free the lateral and anterior aspects of the bladder neck. The surgeon's finger carefully detaches the urethra and bladder neck from the posterior aspect of the pubic bone (Figure 35.5)
 - Indigo carmine is given intravenously to aid in visualizing the ureteral orifices and the urethral or bladder neck edges may be trimmed to expose fresh healthy tissues before formal closure

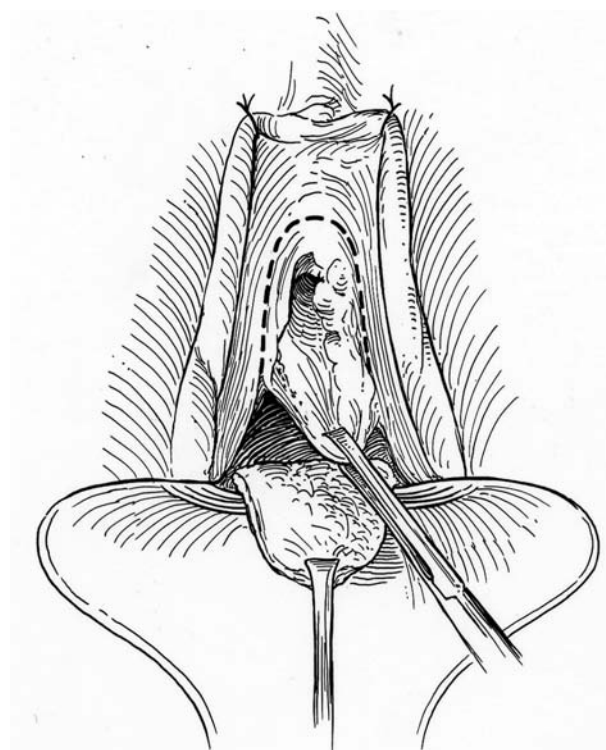


Figure 35.3 Elevated broad-based vaginal flap.

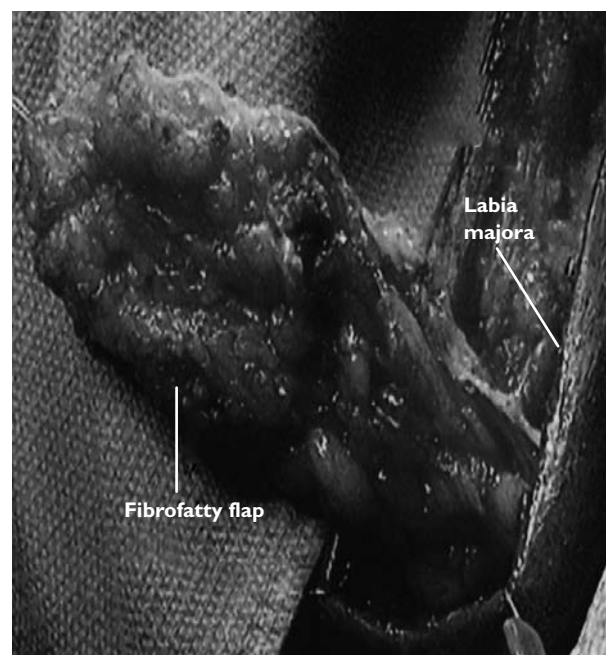


Figure 35.4 Long Martius labial fat pad raised over a posterior inferior pedicle. This step is done before the retropubic dissection to minimize blood loss later on.

- Bladder neck closure
 - First close the bladder neck in a vertical fashion with absorbable running suture (Figure 35.6)

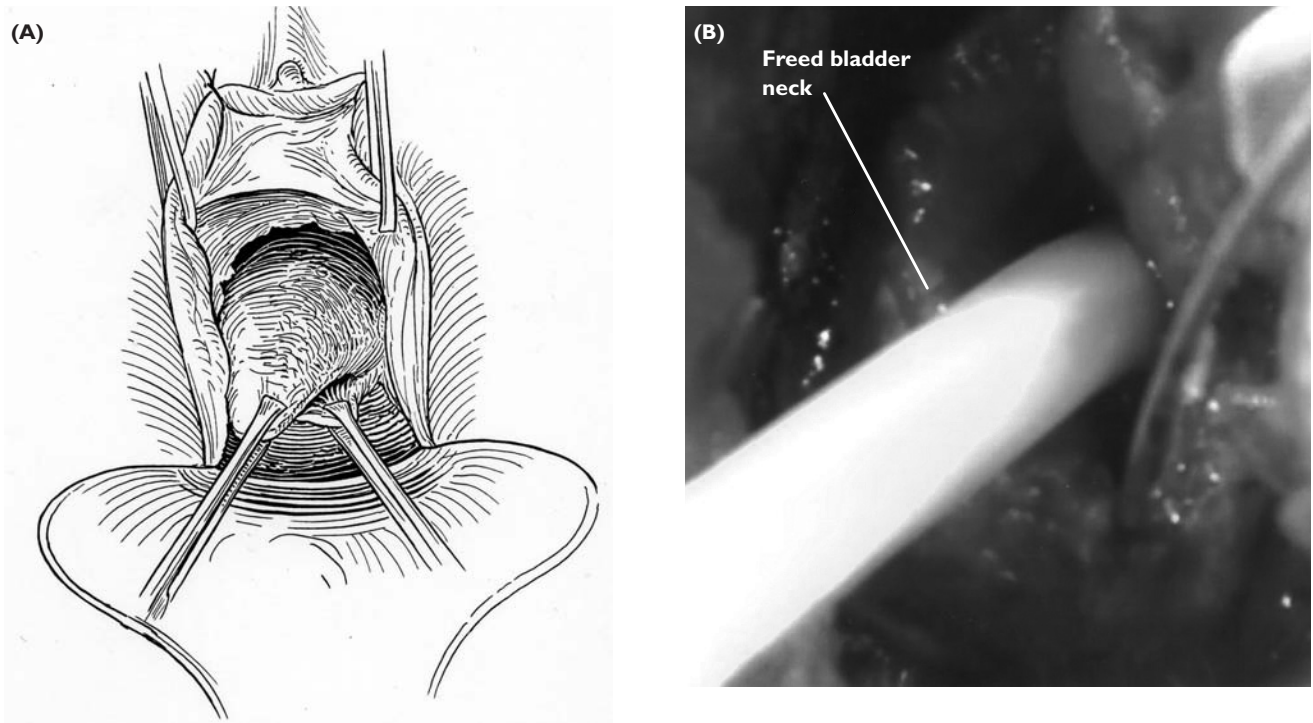


Figure 35.5 (A) Bladder neck detached from anterior and lateral attachments. (B) Large bladder neck completely mobilized all around. The edges have been trimmed.

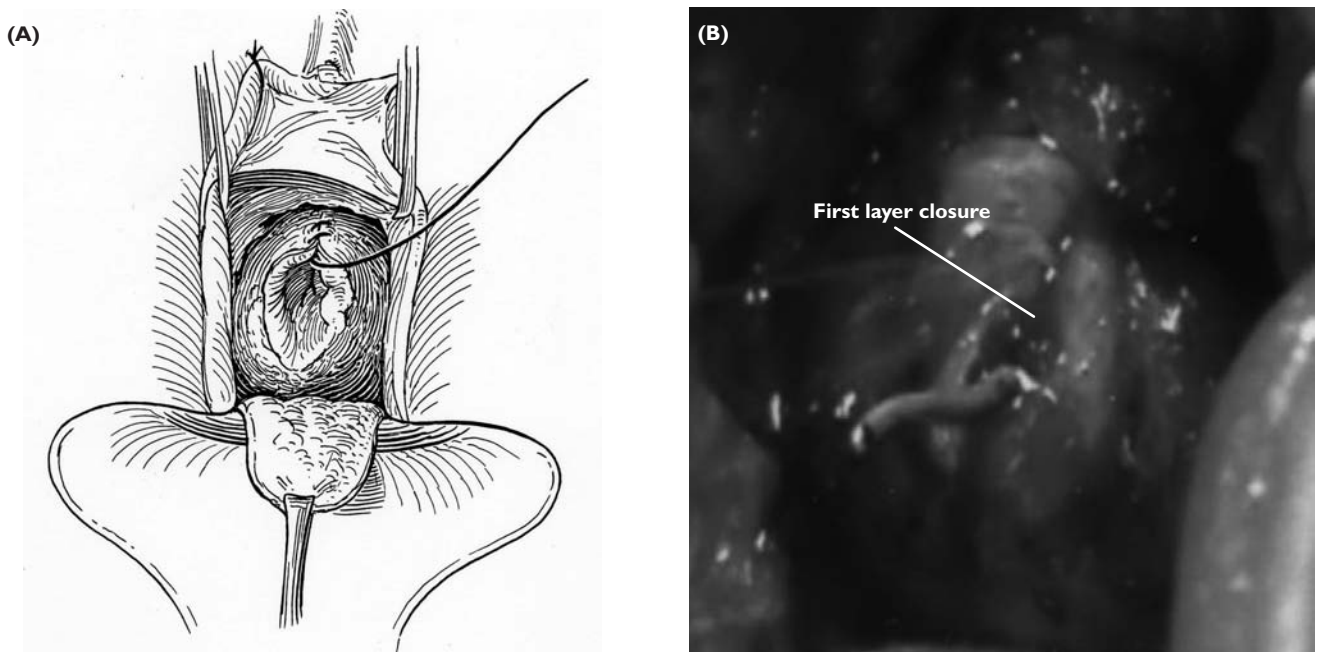


Figure 35.6 (A) First layer vertical closure of bladder neck with tension-free anastomosis. (B) Bladder neck closure starts at each extremity and ends up in the midline. A guide wire inserted through the suprapubic tract guides the closure to avoid leaving any gap in the running closure.

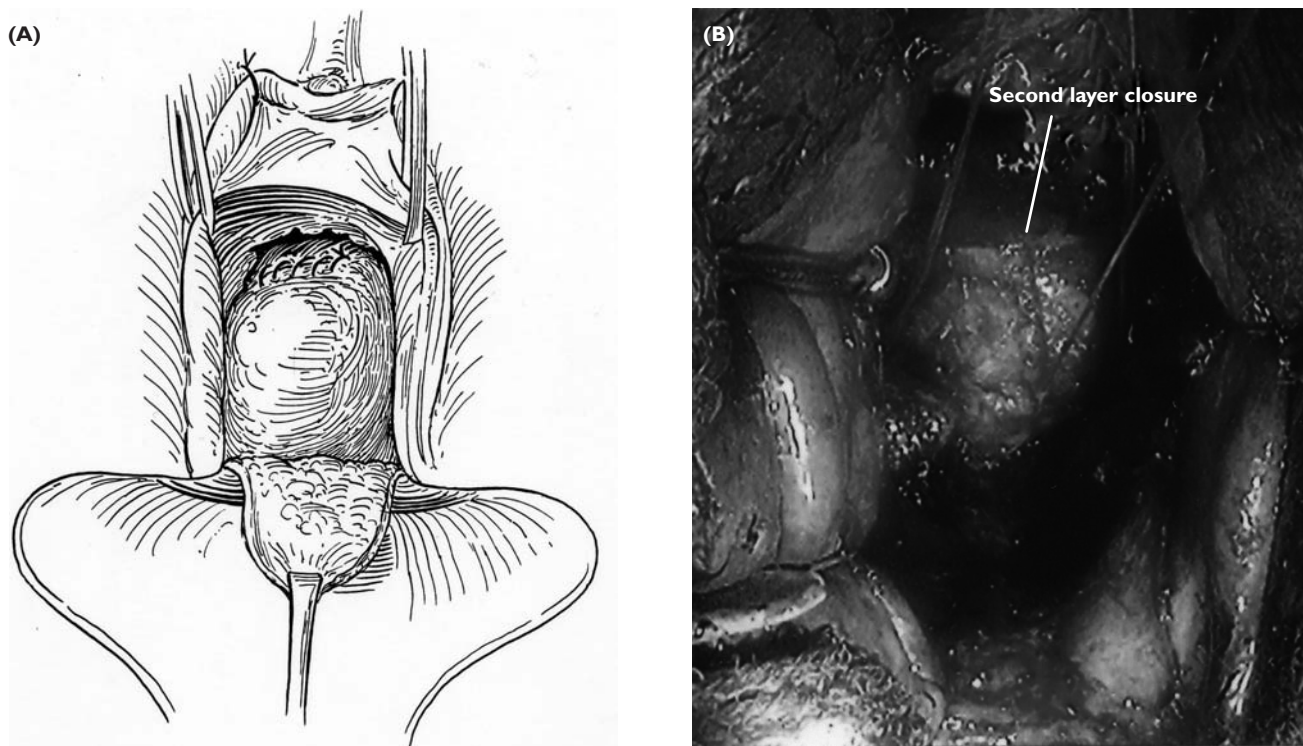


Figure 35.7 (A) and (B) The second layer closure of the bladder neck is performed with several absorbable interrupted Lambert sutures to rotate the outlet upward and avoid leaving the closed bladder neck in a dependent position that could lead to secondary vesicovaginal fistula formation. The corner sutures of this second layer are left long with their needles to anchor in place the labial fat pad graft later.

- Check integrity of the closure by filling the bladder by gravity through the suprapubic tube
- A second horizontal layer of interrupted absorbable sutures serves to both imbricate the first layer and transfer the closed bladder outlet to a position high behind the symphysis pubis, thus rotating it into a non-dependent position (Figure 35.7). This closure directs the force of bladder spasms away from the bladder outlet, thereby reducing the likelihood of secondary vesicovaginal fistula
- Martius flap placement
 - Tunnel the flap created earlier beneath the vaginal wall and fix it in place over the bladder neck closure with absorbable sutures (Figure 35.8)
 - Close labial incision over a small suction drain
- Vaginal flap advancement
 - Advance the vaginal flap to close the vaginal incision with running absorbable suture (Figure 35.9)
 - Irrigate suprapubic tube to ensure patency and no bleeding
 - Pack vagina with antibiotic-soaked gauze for 24 hours.

Abdominal approach (female)

An abdominal approach is desirable for the patient with a history of pelvic radiation in whom vaginal tissues may be poorly vascularized and in whom omental interposition between the bladder neck and vagina is desirable. It is also the approach of choice in the patient who elects for a continent efferent limb (bowel or appendix), an ileovesicostomy, or who has failed a prior attempt at vaginal closure of the bladder neck.⁵ Advantages of this approach include easier positioning if lower extremity contractures or perineal skin breakdown exist. The disadvantages include increased morbidity from an abdominal incision and exposure of bowel, increased chance of bowel injury, a more difficult deep retropubic dissection with risk of bleeding, and the possibility of vesicourethral fistula formation secondarily.

- Position: low lithotomy for continuous access to the vagina. Alternative: supine position if lower extremity contractures prohibit lithotomy position
- Place urethral catheter
- Infraumbilical incision

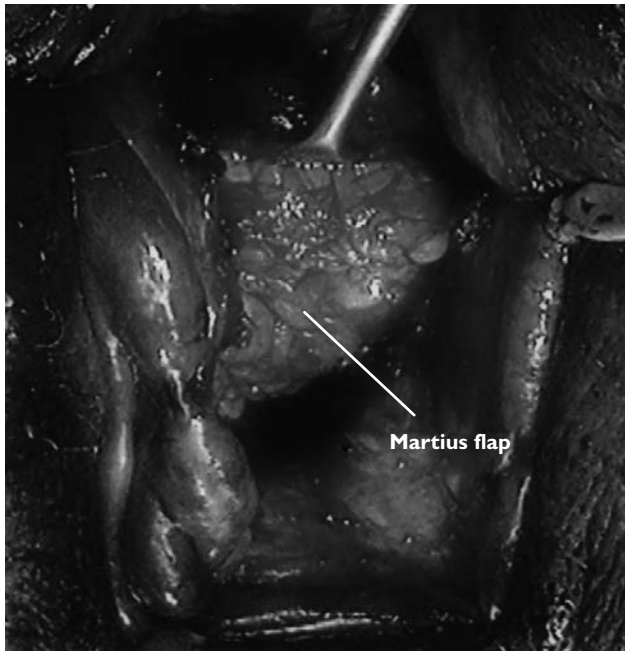


Figure 35.8 After being tunneled along the lateral vaginal wall, the Martius flap is positioned over the closed bladder neck.

- Provides excellent exposure
- Can be extended for omental harvest or use of bowel for an efferent catheterizable limb
- Bladder neck exposure
 - Dissect the prevesical space (of Retzius)
 - Identify the bladder neck and urethra by palpating the balloon of the Foley catheter
 - Control bleeding by suturing the retropubic veins
 - Divide the anterior bladder neck
 - Place ureteral catheters before starting the dissection of the posterior bladder neck
 - Place a finger or a sponge stick in the vagina to help identify and maintain the appropriate plane of dissection between the posterior bladder neck and the anterior vaginal wall. Free the posterior bladder neck from the anterior vaginal wall. Continue until the bladder neck can be rolled up out of a dependent position
 - Trim the edges of the bladder neck to allow approximation of healthy tissues and remove the ureteral stents before closing the bladder neck with running or interrupted sutures
- Urethral stump closure (when present)
 - Close the urethral stump with two layers, invert the first layer, then oversew the edges

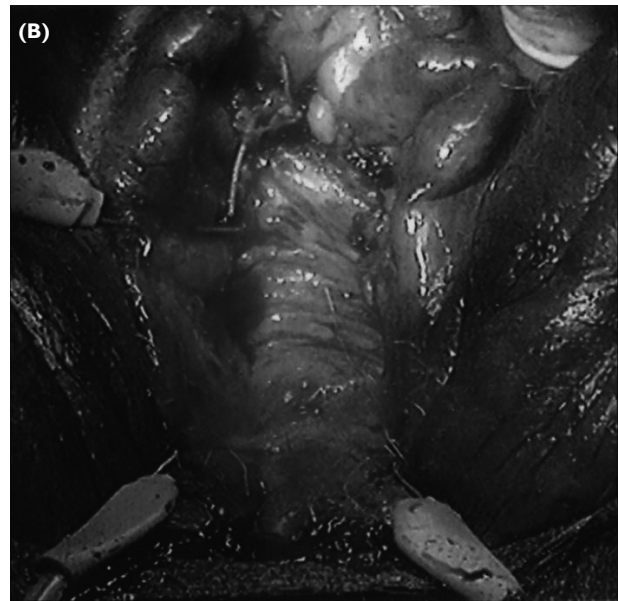
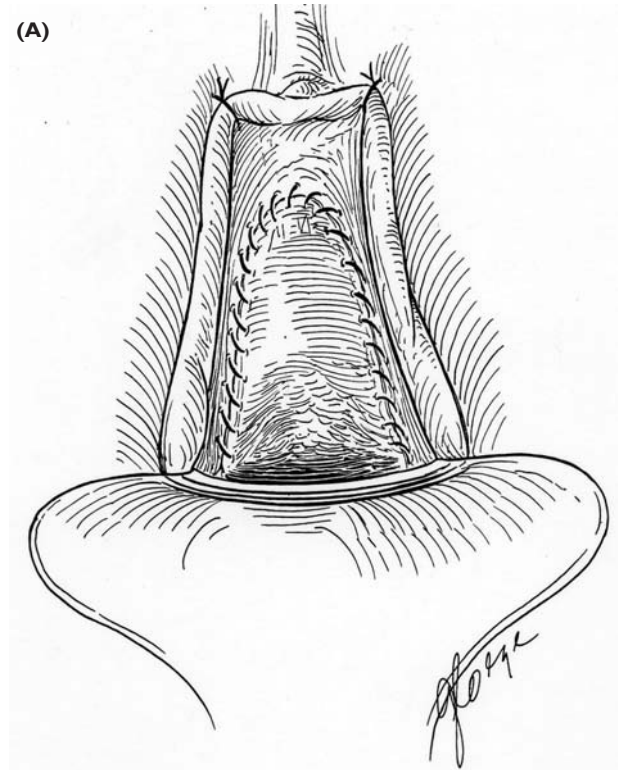


Figure 35.9 (A) and (B) The initially raised large anterior vaginal wall flap is advanced over the underlying closed bladder neck and labial fat pad graft. A vaginal pack is then placed for 24 hours.

- Drainage
 - If an incontinent vesicostomy or catheterizable efferent limb is selected for postoperative bladder drainage, they may be fashioned at this time
 - Otherwise, a large-bore (24 Fr) Malecot or Foley catheter is placed in the bladder dome

through a lateral, short incision. The bladder neck is then closed in two layers as described for vaginal closure

- Tissue interposition
 - It is recommended that an interposition graft be placed between the bladder outlet and the urethral stump to prevent vesicourethral fistula
 - Omentum, peritoneum, rectus muscle, or perivesical fat pad are the most commonly used and are discussed further below.

Approach in the male

The perineal approach to BNC, though conceptually and technically feasible, is not considered to be the procedure of choice in the male. The abdominal approach is preferred and has two distinct advantages over perineal closure: the bladder neck can be rotated anteriorly and out of a dependent position, and the choices for vascularized interposition are abundant (omentum, rectus flap, and peritoneal flap). Two techniques have been employed for abdominal closure of the bladder neck: supraprostatic and infraprostatic closure. Our technique of choice has been supraprostatic bladder neck closure as it offers several distinct advantages over infraprostatic closure. It is technically easier and does not involve deep pelvic dissection or transection of the dorsal venous complex. It allows for a better mobilization of the bladder neck, resulting in a tension-free closure. Finally, it provides the opportunity for future fertility as an antegrade flow of ejaculate is preserved. Concomitant prostatectomy is generally not indicated unless a strictured urethra or prostatorectal fistula poses a problem to postoperative prostatic drainage. When BNC is to be performed in conjunction with salvage prostatectomy, the extirpative portion of the procedure is performed first. One group reported a method of performing bladder neck detachment and augmented closure incorporating total prostatectomy and urinary diversion in men with complex bladder and urethral pathology.⁶

The supraprostatic approach for BNC in the male patient is outlined below.

- Position: low lithotomy or supine
- Place urethral catheter
- Make an infraumbilical vertical midline incision and assess the retropubic space
- Identify the bladder neck and use absorbable suture to ligate the superficial dorsal venous complex at the prostatovesical junction

- Divide the anterior vesical neck at the junction with the prostate
- Deflate and remove the Foley balloon to allow visualization of the posterior bladder neck. Place ureteral catheters
- Transect the posterior bladder wall and identify the plane between the bladder and the rectum
- Mobilize the posterior bladder neck from Denonvillier's fascia and rectum. Avoid excess mobilization to prevent injury to the ureters or vascular pedicles of the bladder
- Place a large bore suprapubic tube through a separate stab incision. If an alternative bladder drainage method is desired, it may be constructed at this time
- Perform bladder neck closure by one of two methods
 - For a larger bladder neck, or where closure is more difficult, the outlet is closed in two layers as described above
 - For a smaller bladder neck, a series of two absorbable purse-string sutures may be used to invert the outlet similar to the inversion of an appendiceal stump
- Flap
 - Place a well vascularized flap of omentum, rectus muscle, or peritoneum in the space between the bladder neck closure and the prostate to facilitate healing and to help prevent fistulization.

Vascularized interposition after abdominal bladder neck closure

Following the BNC it is highly advisable to interpose vascularized tissue between the bladder neck and the pelvic outlet to reduce the risk of secondary fistula. Choices include omentum, a rectus flap, or a flap of paravesical fat or peritoneum; however, vascular supply of the latter may not be as reliable as omentum or rectus flap.⁷

- Omental flap
 - We prefer omentum because of its size, reliable blood supply, and abundant lymphatic drainage
 - A tongue may be easily mobilized with only limited dissection in patients with a generous omentum⁷
 - If, however, the patient is extremely thin, or has a history of radiation or prior intra-abdominal surgery, a more extended incision may be needed and the omentum may be mobilized on a pedicle supplied by the right gastroepiploic

artery. The right side is preferred due to its more dependent position and more generous blood supply

- The omentum is sutured into place with absorbable sutures
- Rectus flap
 - If a rectus flap is chosen, it may be mobilized and based on an inferior epigastric vascular pedicle with careful attention to all lateral vascular collaterals
 - The rectus flap is then rotated downward and positioned as described above for omentum. An advantage to this flap is that a suprapubic approach can be utilized without entering the peritoneum
 - A suction drain is left in the pelvis and brought out through a separate stab wound along with the suprapubic catheter.

POSTOPERATIVE CARE

Postoperative intravenous antibiotics are used for 3–5 days after which patients are placed on daily oral antibiotic suppression. The suction drain is usually left for a few days. In our experience a nasogastric tube is not necessary except for extensive dissection and when bowel segments are used. The suprapubic tube is carefully secured to avoid kinking or dislodgment. Patients are kept on either oral or rectal anticholinergic medication (oxybutynin with or without belladonna and opium suppositories) to prevent bladder spasms. A cystogram is obtained at 2–3 weeks to document the integrity of BNC. If there is no evidence of leak or fistula, the suprapubic tube may be changed or removed if a catheterizable stoma was chosen for bladder drainage.

COMPLICATIONS

The primary complication of BNC is postoperative fistula which may occur early or late. Prevention of fistula formation is accomplished by bladder neck dissection to allow closure in a non-dependent position, careful debridement of the bladder neck edges, use of two non-overlapping suture lines for bladder neck closure, interposition of well vascularized tissue over the closure, and avoidance of postoperative bladder spasms. When a fistula is suspected, the patient should undergo a cystogram. When a small fistula is encountered early in

the postoperative period, bilateral percutaneous nephrostomies may be used to divert the urine in the hope of spontaneous closure of the fistulous site with prolonged drainage. Reoperation is usually necessary. When the initial procedure was performed from a vaginal or perineal approach, reoperation should be performed suprapubically to allow extensive bladder mobilization and interposition of a large, well vascularized omental flap. Supravesical diversion with or without cystectomy is reserved for patients in whom all other attempts at repair have failed.

Loss of access to the bladder may also represent a source of postoperative morbidity. Loss of a suprapubic tube and closure of its tract is an underreported but not uncommon complication. Access may be re-established by using a flexible cystoscope or ureteroscope and may require fluoroscopy to negotiate the tract and pass a flexible wire down to the bladder. If this procedure fails, the patient may be given a fluid bolus and the bladder may be percutaneously accessed under sonographic guidance. Once access has been established, the tract may be dilated and a Council catheter passed over the wire. Inability to catheterize a continent efferent limb may be treated similarly and endoscopic negotiation of the conduit usually suffices to re-establish access.

RESULTS

Though a number of authors have reported their results with BNC, most series have been small, retrospective, and with a great deal of variability in technique.^{1,5,8} Consequently, long-term outcomes and overall success rates are difficult to judge. In series where the bladder neck is anteriorly mobilized and appropriate vascularized interposition is utilized, long-term continence rates range from 85 to 100% with a 7–8% reoperation rate.^{1,5,8} In series where these principles have not been employed, fistula formation and reoperation rate range from 30 to 46% and 25 to 46%, respectively.^{9,10} In one series where female multiple sclerosis patients were treated with vaginal urethral closure and suprapubic cystostomy, approximately 80% of the patients who were continent (with or without an early revision) and available for reliable follow-up remained continent at an average follow-up of 6.5 years (range 2–17 years).¹⁰ Upper tract deterioration has been noted in a single series (11%) and has been causally related to the use of continent, catheterizable efferent channels in patients with persistent bladder dysfunction.⁹

CONCLUSION

BNC is an uncommon procedure reserved for rare indications in challenging patients. It is a difficult procedure which requires meticulous attention to detail for success. Several guiding concepts must be adhered to for a successful closure and to prevent breakdown of the repair with a secondary fistula. Key steps include wide mobilization of the bladder neck out of a dependent position; multilayer, non-overlapping, tension-free closure; and interposition of a well vascularized flap between the closed bladder neck and the pelvic outlet.

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36 Urinary diversion during laparoscopic radical cystectomy

Amr Mahmoud Abdel Hakim

Laparoscopy in urology has progressed significantly during the past 20 years, from simple ablative procedures to increasingly complex reconstructive procedures.¹ Advances are most clearly reflected by the establishment of laparoscopic radical prostatectomy, with a noteworthy decrease in patient morbidity and hospital stay.²⁻⁴ Laparoscopic cystectomy was first reported in 1992. This was for benign recurrent, symptomatic pyocystitis.⁵ Subsequently, isolated clinical reports of laparoscopic radical cystectomy (LRC) for muscle invasive bladder cancer were reported. The procedure has been confined to a few centers in the world because of its high technical demand. The pelvic cavity is small and there are complex vascular structures surrounding the bladder.⁶ In all of these reports, a metastatic work-up was done to rule out distant metastasis, and abdominal computed tomography (CT) was done to rule out extravesical extension.⁷

Reviewing MEDLINE, more than 100 papers are found discussing LRC, with more than 50% of these being published after 2004.

The technically challenging urinary diversion was not attempted laparoscopically in the early reports. Later, almost all types of urinary diversion were used in association with LRC. This delicate reconstructive aspect of the procedure was performed through either a 'minilaparotomy' incision, by exteriorization of the bowel through an enlarged port site incision or a small Pfannensteil incision.⁸⁻¹¹ After preparation of the pouch extracorporeally, the ureterointestinal anastomosis and the urethra-neobladder anastomosis could be performed conventionally or the latter done laparoscopically. In other reports, the diversion was performed totally intracorporeal.

Sanchez de Badajoz et al reported on laparoscopic radical cystectomy and ileal conduit in 1995. The bladder was dissected free and extracted whole through the right flank. The right ureter and a loop of intestine were withdrawn through the same incision. An ileal segment was isolated and intestinal continuity restored. The right ureter was anastomosed to one extreme of the segment that was then reintroduced into the abdomen, taken across to the left side,

withdrawn with the left ureter, anastomosed extracorporeally, and reintroduced.⁹

Puppo et al described five cases of anterior pelvic exenteration in females through a combined transvaginal and laparoscopic approach for bladder cancer. As far as urinary diversion is concerned, a bilateral cutaneous ureterostomy was performed in the first case, and in the remaining four an ileal conduit was accomplished through a minilaparotomy at the stoma site. The surgical specimen was withdrawn 'en bloc' transvaginally in all cases except one, in whom a midline minilaparotomy was performed.⁸

Denewar et al reported on ten patients with invasive bladder tumors that were submitted to laparoscopic assisted cystectomy and lymphadenectomy. The specimen retrieval and continent pouch construction was performed through a limited abdominal incision. The specimen was retrieved from an 8 cm midline incision.¹²

Gill et al reported LRC with ileal conduit urinary diversion performed totally intracorporeally.⁷ This report was an initial report on two male patients. A 15 cm segment of ileum was identified 15 cm proximal to the ileocecal junction. It was isolated using the Endo-GIA (Tyco/Healthcare/United States Surgical, Norwalk, CT, USA) stapler that was also used to establish gastrointestinal tract continuity by a side-to-side anastomosis. The left ureter was delivered to the right side under the sigmoid mesocolon. The distal end of the loop was exteriorized through the preselected stoma site and the stoma was created. Using a laparoscopic electrosurgical J-hook, a small ileotomy was performed at the site planned for the ureteral anastomosis. After spatulating the cut edge of the ureter the anastomosis was then completed with running continuous sutures.

Turk et al reported on a series of LRC in five patients with invasive transitional cell carcinoma. For urinary diversion, a rectosigmoid pouch was created completely intracorporeally. Starting from the rectosigmoid junction, the intestine was antimesenterically incised with an electric hook 10 cm in distal and proximal directions. In men, the entrapped specimen was removed transanally via the opened rectum. The posterior walls

of the rectum and sigmoid were anastomosed side-to-side, forming the posterior wall of the pouch with continuous 3-0 polyglactin suture. The mobilized ureters were drawn through this posterior wall and sutured in a prepared 3 cm submucosal bed. After insertion of 8 Fr single-J ureteral catheters via the opened rectum, suturing the mucosa over the ureters formed the submucosal tunnel. The stents were then passed out transanally to drain the pouch externally. Finally, the anterior wall of the pouch was closed with continuous 3-0 polyglactin suture, and a drain was left through the lateral 5 mm trocar site.¹⁰

Orthotopic continent neobladder has emerged as the preferred approach for urinary diversion following radical cystectomy because of the superior quality of life. Advantages of orthotopic neobladder include near normal voiding mechanics, elimination of the need for external appliances, and superior body image.¹³ Construction of a neobladder following laparoscopic radical cystectomy has been reported in a number of studies. Some have reported on them being performed by open assisted techniques.^{14–16} Gill et al reported on their initial experience with a continent orthotopic neobladder, following laparoscopic radical cystectomy, performed completely intracorporeally.¹⁷

In the series by Abdel-Hakim et al,¹⁴ they reported on nine patients (eight males and one female) with invasive transitional cell carcinoma and verrucous squamous carcinoma, who underwent laparoscopic radical cystectomy with ileal neobladder through five transperitoneal ports (Figure 36.1).

Abdel-Hakim et al used the Y-neobladder for diversion, as it has been described by Fontana et al.¹⁸ In their first three male patients, a midline subumbilical minilaparotomy was done, later a 3–5 cm muscle splitting incision at the site of the right 10 mm port was used for specimen extraction and neobladder construction (Figure 36.2). The bladder was removed and a 32–36 cm loop of the terminal ileum was chosen. In their last six cases the site of the right 10 mm port was extended by a muscle splitting 3–5 cm incision. The 32 cm loop of the terminal ileum was pulled extracorporeally (Figure 36.3). The selected loop was isolated and the intestinal continuity was restored by end-to-end anastomosis using running 3-0 Vicryl. The isolated loop was transformed into a 'U' shaped loop with three 3-0 silk sutures. The open ends were closed by running 3-0 Vicryl transforming the loop into a Y-bladder (Figure 36.4). A 2 cm long incision was made on the posterior aspect of the free limbs of the 'Y' to prepare the site of ureteral anastomosis. Two 8 Fr feeding tubes were passed from the anterior surface of the two



Figure 36.1 Port arrangement for laparoscopic radical cystectomy with ileal neobladder.



Figure 36.2 Small muscle splitting incision at the right 10 mm port site.

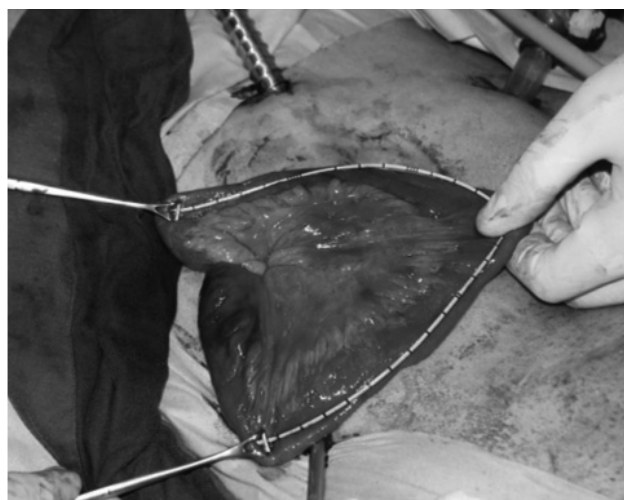


Figure 36.3 The selected ileal loop is exteriorized through the small incision.



Figure 36.4 Fashioning of the neobladder.



Figure 36.5 Wound closure and restoration of pneumoperitoneum.

'Y' limbs and through the two openings made for ureteral anastomoses.¹⁴

In their first three cases, the ureteral and urethral anastomoses were completed extracorporeally. However, in the last six cases, the 12 mm port was reinserted, the wound tightened around it, and pneumoperitoneum restored (Figure 36.5). The pouch was identified, making sure that the mesentery was not twisted. Five 2/0 Vicryl sutures around 20 Fr silicon Foley catheter sutured the open end at the apex of the loop to the urethra. The ureters were anastomosed to

the ileum end-to-side by running 4/0 Vicryl around an 8 Fr tube. The 8 Fr stents were extracted through the 5 mm ports. Two 20 Fr tube drains were passed through the 10 mm ports and fixed.

Gaboardi et al also reported on LRC with pelvic lymphadenectomy and ileal orthotopic neobladder reconstruction in a single 72-year-old male patient. Their technique was developed after anatomic and surgical studies on cadavers. They tried two minimal surgical abdominal accesses in ten cadavers with a similar small body mass. In five cadavers, a 5 cm supraumbilical access guaranteed good isolation of the ileal loop and easy tailoring of the anastomosis. In the remaining five cadavers, a subumbilical approach did not allow good isolation of the ileal loop in three of the five patients, while in two the anastomosis was easily completed.¹⁵

Through the abdominal incision the ileum was extracted and 25 cm of bowel were isolated 15 cm proximal to ileocecal junction. An external stapled side-to-side anastomosis was done to restore bowel continuity and the isolated bowel segment was detubularized and partially fashioned. All this was then carefully reinserted into the abdomen.¹⁵ Following this the abdominal incision was closed and pneumoperitoneum was created again. The distal end of the neobladder was identified and used to create the posterior wall of the urethra-neobladder anastomosis using 3-0 absorbable stitches. Non-refluxing ureteral anastomoses were created using a nipple mechanism.¹⁹ Two stents were passed through a trocar and inserted into the ureters up to the kidneys. The urethra-neobladder anastomosis was then completed on a 20 Fr Foley catheter, and then a continuous 3-0 absorbable suture closed the anterior neobladder wall.

In 2002 Gill et al reported on the first completely intracorporeally constructed neobladder following laparoscopic radical cystectomy.¹⁷ Another study reported on a completely intracorporeal technique of laparoscopic orthotopic ileal neobladder following cystectomy in 12 survival porcine animals.²⁰ The report by Gill et al included three patients (one female 42 years, two males 55 and 57 years) with muscle invasive transitional cell carcinoma. In the female patient, there was a surgical history of open left radical nephroureterectomy for upper tract transitional cell carcinoma and transabdominal hysterectomy for endometrial cancer. An ileal neobladder with a Studer limb was performed in two cases. In the third patient, urethral involvement precluded orthotopic neobladder, so an Indiana pouch with a continent catheterizable stoma was created.¹⁷ A six port transperitoneal approach was used.

After the laparoscopic radical cystectomy was done, an additional 5 mm port was inserted in the midline, midway between the umbilicus and symphysis pubis. The laparoscope was repositioned in the left lateral port, pointing towards the liver, with the surgeon working through the midline infraumbilical port and right pararectal port. The ileocecal junction was identified and a 65 cm segment of ileum was selected using a malleable foot ruler inserted into the abdomen. Division of the distal end of the selected segment was done with a 35 mm Endo-GIA and 25 mm GIA for the mesentery.¹⁷

In a similar manner, the proximal end of the ileal segment and the mesentery was done using a single firing of the stapler. The excluded ileal segment was dropped posteriorly, and a side-to-side anastomosis was done to restore bowel continuity using Endo-GIA. The window in the ileal mesentery was closed with three interrupted sutures. The proximal 10 cm of the ileal segment was left intact for the Studer limb. The remaining distal 55 cm length of the ileal segment was detubularized along its antimesenteric edge using a combination of electrosurgical endoshears and the harmonic scalpel. Before this, the ileal segment was irrigated to prevent peritoneal soiling. Continuous intracorporeal suturing of the corresponding edges of the detubularized segment then created the posterior plate of the neobladder using 2-0 absorbable suture. The plate was then delivered into the pelvis towards the urethral stump taking care not to twist the mesenteric pedicle. The urethral anastomosis was performed in the most dependent part along the apex of the urethral plate using continuous 2-0 absorbable suture. A 22 Fr silicone Foley catheter was inserted per urethra before completing the urethral anastomosis.¹⁷

In the female patient, a single-J ileoureteral stent was inserted via the external urethral meatus alongside the Foley catheter into the neobladder. In the male patients the ileoureteral stents were inserted through the right lateral port that was removed and reinserted alongside the stents. The anterior wall of the neobladder was folded over and suture approximated to achieve a globular configuration. Before completion of the anterior wall, the stents were delivered into the Studer limb and retrieved through two separate ileotomy incisions (sites of the ureteroileal anastomoses). Bilateral ureteroileal anastomoses were performed sequentially starting with the right side (more distal). The anastomosis was done using two separate 3-0 absorbable sutures in a continuous manner, with one suture each for the anterior and posterior ureteral walls. Before completion of the anastomosis, the stents were advanced into the renal pelvis.

All suturing and knot tying was performed through intracorporeal free-hand suturing and knot tying. The specimen was retracted through a 2–3 cm extension of the umbilical port. The drains were placed through each lateral port site.

Robotic cystectomy was pioneered by Menon et al and was rapidly adopted by others.^{16,21} Menon et al reported on 14 men and three women with transitional cell carcinoma of the bladder who underwent robot assisted radical cystoprostatectomy (RRCP) using the da Vinci surgical system (Intuitive Surgical, Sunnyvale, CA, USA). The technique was developed in two patients in Detroit and modified in Mansoura, Egypt. After excision, the specimen was entrapped in an Endocatch II bag (Tyco/Healthcare/United States Surgical, Norwalk, CT, USA) and retrieved through a 5–6 cm midline subumbilical incision. Ileal conduit, 'W' pouch with a serosal-lined tunnel, and 'T' pouch with a serosal-lined tunnel were performed through the same incision in three, ten, and two patients, respectively. The pouch was placed in the pelvis and a Foley catheter passed urethrally into the pouch. The abdominal incision was then closed and the robot re-docked for anastomosis of the neobladder to the urethra.¹⁶

Prostate sparing radical cystectomy has been performed in some centers. In these selected cases the neobladder is anastomosed to the prostatic fossa.²¹

The question of refluxing or non-refluxing ureteroileal anastomosis is still controversial. Those who favor the antireflux technique assume that bacteriuria is a frequent finding in patients with orthotopic substitutes and that there is potential for high intrareservoir voiding pressures.^{29–32}

Those against reflux prevention suggest that an antireflux mechanism in an orthotopic bladder substitute is unnecessary based on the following.

- (1) As a result of bowel detubularization and reconfiguration, the neobladder should accommodate a large volume of urine at low intrareservoir pressures.
- (2) Urine in the orthotopic bladder should be sterile.
- (3) Complete emptying of the neobladder is routinely performed with Valsalva's maneuver (increased abdominal pressure) and simultaneous relaxation of the external sphincter. In this situation, intra-abdominal pressure theoretically affects the neobladder, ureters, and renal pelvis. This concomitantly directed pressure prevents urinary reflux and protects the upper urinary tract.
- (4) The incorporation of an antirefluxing system is technically more challenging compared with the

more simple refluxing systems, which are, in general, less surgically demanding and potentially less time-consuming intraoperatively.

- (5) An antireflux mechanism may be associated with higher rates of complication, particularly obstruction. Complications of non-neoplastic obstruction with the antireflux Camey-Le Duc ureteral implantation technique have been reported to occur in 7–29%.^{23–26} If so, the complications associated with an antireflux system may outweigh the potential benefits of preventing reflux.³³
- (6) The harmful effects of the urinary constituents (secondary to reflux) have been demonstrated only in animal models. Again, the rise in intravesical pressure occurs momentarily during straining for voiding. Clean intermittent catheterization is needed in up to 40% of patients with orthotopic neobladder, hence the rise in intravesical pressure is not important.

The final point to be addressed in this chapter is the use of staples in pouch creation. Staples are being increasingly used in the construction of the urinary tract.^{34–37} The advantage of staple use is the reduced operative time. However, the added cost to an already expensive procedure and the concern regarding stone formation on the suture line has limited their use. Recently, Fontana et al published their experience in construction of the Y-neobladder using staples. The reservoir was created in 20 minutes. The incidence of stone formation on the staples was 6%, which is comparable with the incidence on sutures lines (5–12.9%).^{38–40}

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37 Ileal neobladder

Richard E Hautmann

PATIENT SELECTION

By 2007 all cystectomy patients were candidates for a neobladder, and those patients in whom orthotopic reconstruction may be less ideal should be identified. Compromised renal function as a result of long-standing obstruction or chronic renal failure, with serum creatinine levels of more than 150–200 $\mu\text{mol/l}$, is an absolute contraindication to continent diversion of any type. Severe hepatic dysfunction is also a contraindication to continent diversion. Patients with compromised intestinal function, particularly inflammatory bowel disease, may be better served by a bowel conduit.

Orthotopic reconstruction is absolutely contraindicated in all patients who are candidates for simultaneous urethrectomy, based on their primary tumor. The number of relative contraindications and comorbidity is steadily decreasing. However, some of them, such as mental impairment, external sphincter dysfunction, or recurrent urethral strictures, deserve serious consideration.^{1,2}

FACTORS IN FAVOR OF A NEOBLADDER

The key factor in determining which patients should be candidates for a neobladder is the patient's desire. The patient needs a certain motivation to tolerate the initial and sometimes lasting inconvenience of nocturnal incontinence associated with a neobladder. Most patients accept some degree of nocturnal incontinence for the benefit of avoiding an external appliance, but not all patients do, and realistic expectations of the functional outcome are essential. The psychological damage and stigma experienced by a patient who enters surgery expecting a neobladder, but awakens with a stoma, are increasingly recognized.^{1,2}

FACTORS AGAINST A NEOBLADDER

There are patients who are better served with a conduit than a neobladder. The following factors are against a neobladder:

- (1) The patient's main motivation is to 'get out of the hospital as soon as possible' and resume normal, rather sedentary activities. Many frail patients undergoing cystectomy will have less disruption of normal activities with a well-functioning conduit than an orthotopic reservoir associated with less than ideal continence.
- (2) The patient is old and living in social isolation.
- (3) The possibility of regular follow-up or patient compliance is low, or the patient is of advanced age.
- (4) The patient is unconcerned about body image. Most older patients do not have the same concerns that a younger patient might have, and their main goal is returning to their previous lifestyle, which is often quite sedentary.^{1,2}

ONCOLOGIC FACTORS

Following cystectomy, the rhabdosphincter must remain intact. Nevertheless, operation for cancer must not be compromised. This concern applies to two aspects of selection: urethral tumor recurrence in men and the use of orthotopic replacement in women.

One of the initial deterrents to orthotopic diversion that the surgeon encounters is the risk for urethral recurrence of cancer. Historically, the risk following cystectomy has been 10%. The best predictor of the risk for urethral disease is the presence and extent of carcinoma in situ (CIS) in the prostatic urethra, ducts, or stroma. In cases with diffuse CIS in the ducts and invasion of the stroma, the risk for urethral disease has historically been 25–35%, thus discouraging the use of the urethra. Our aggressive approach for neobladder diversion relies only on a frozen section of the urethral margin at the time of surgery. A conservative approach would disqualify patients with any prostatic involvement. Orthotopic bladder substitution in women with invasive bladder cancer has been popularized recently. Analysis of pathologic specimens has supported orthotopic bladder substitution in women who have no evidence of tumor at the bladder neck. Indeed, the majority of invasive cancers are located in the area of the trigone, making a wide excision together with the anterior vaginal wall necessary.

Increasing experience with orthotopic reconstruction supports less restriction of patient selection based on tumor stage. There is no convincing evidence that a patient with an orthotopic diversion tolerates adjuvant chemotherapy less well, or that a pelvic recurrence is any more difficult to manage in a patient with a neobladder, than in one with an ileal conduit. Patients can anticipate normal neobladder function for the rest of their lives.

Our approach respects the patient's desire for a neobladder; if the patient is strongly motivated, he or she gets a neobladder, even when the patient has a poor prognosis and relapse is likely to occur. Previous radiation therapy, especially with an advanced cancer, usually mitigates against an orthotopic diversion, but does not absolutely preclude it. However, all patients should be informed that diversion to the skin, by either a continent reservoir or ileal conduit, may be necessary due to unexpected tumor extent, and an appropriate stoma site should be marked on the abdominal wall beforehand.^{1,2}

PRECONDITIONS OF SUCCESS

The primary goal of bladder replacement is not to improve survival, impact cancer prognosis, or decrease metabolic complications, but rather to improve quality of life. In this regard urinary continence is the key to success. In the daytime this is achieved in almost 100% of patients with an orthotopic bladder, whether constructed from tubularized or detubularized intestinal segments. Nonetheless, nocturnal incontinence is a feature shared by all forms of orthotopic bladder despite the construction of detubularized, low pressure, large capacity, and highly compliant reservoirs.³ Daytime continence is determined by maximum urethral closure pressure. During the night continence is the net result of two forces that have about equal influence but in opposite directions, that is maximum urethral closure pressure versus maximum contraction amplitude plus baseline pressure at mid-capacity.²

In patients with orthotopic bladder substitution the continence result is influenced by the functional characteristics of the distal urethral sphincter and urinary reservoir. Experience with the approach to the membranous urethra (i.e. radical prostatectomy) is mandatory for successful orthotopic bladder replacement. In an effort to preserve as much of the striated sphincter as possible, the technique of nerve-sparing radical prostatectomy is advisable (Figure 37.1).

Preparation of the female urethra requires special attention to surgical detail to avoid damage to the urethra, anterior vaginal wall, and urethral support, which could jeopardize the continence mechanism

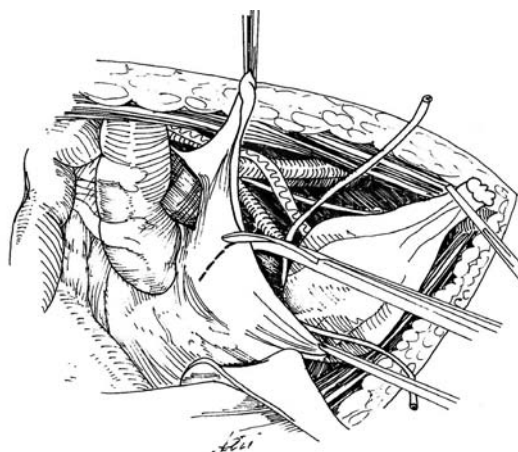


Figure 37.1 Pelvic lymph node dissection has been completed. Ureters are exposed extraperitoneally. Peritoneum over the bladder is bisected to create two large flaps for later extraperitonealization of the neobladder.

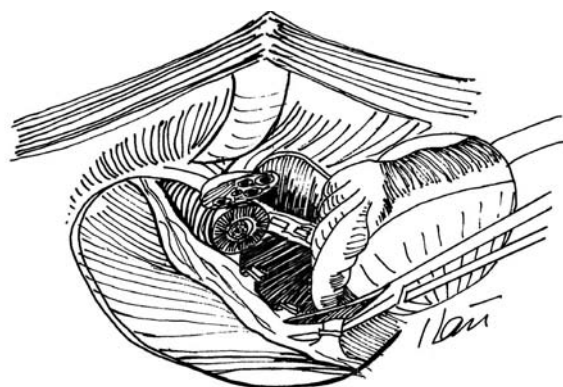


Figure 37.2 Upward traction on the catheter placed through the prostate into the bladder allows the lateral vascular pedicles of the prostate to be easily isolated, controlled with clips, and divided to expose the lateral aspect of the seminal vesicle. Further exposure is gained by division of the vascular bands between the bladder neck and the seminal vesicles and prostate. Neurovascular bundle, membranous urethra and pelvic floor structures are ideally exposed.

and micturition. The endopelvic fascia is incised immediately lateral to the posterior urethra at the urethra-vesical junction. As much of the urethra-pelvic ligament and para-urethral vascular and nerve plexus as possible must be saved (Figure 37.2).

OPERATIVE TECHNIQUE

Peritoneal flaps for extraperitonealization of the ileal neobladder

Depending on tumor stage and location, the bladder is completely extraperitonealized, and the peritoneum is

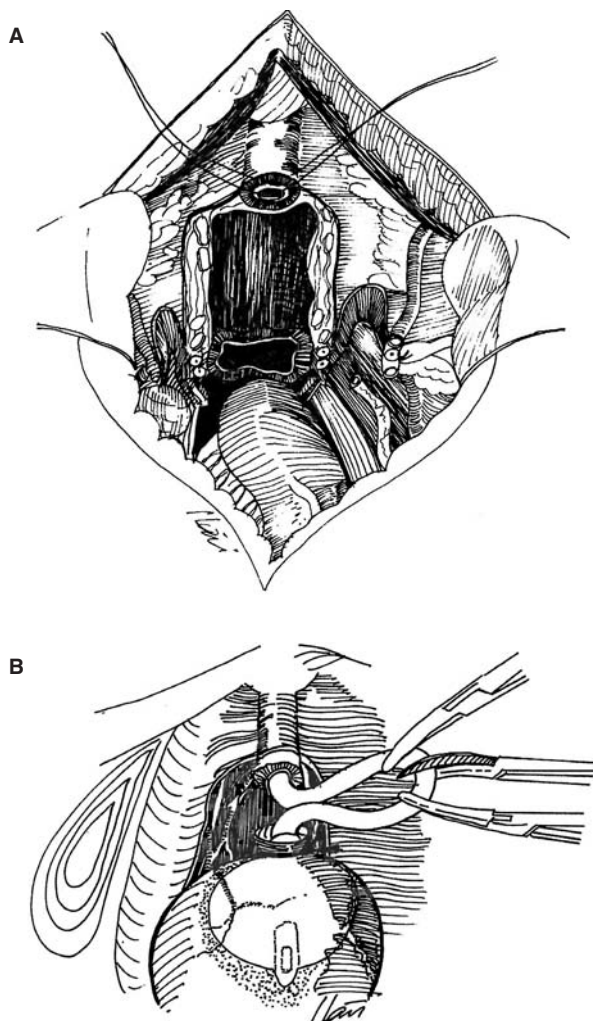


Figure 37.3 (A) Final result of a precise modified nerve-sparing anterior exenteration with maximum preservation of the urethral support structures, the bottom of this defect being the anterior vaginal wall. (B) Resection of the bladder must be done slightly distal to the vesicourethral junction. This is guaranteed by ligating the Foley balloon in the bladder. Furthermore, spillage of tumor cells from the bladder is thus prevented.

bisected over the bladder (Figure 37.3A). If this cannot be done safely, an incision in the peritoneum is made high on the base of the bladder, leaving a peritoneal patch on the posterior bladder wall. A vertical incision lateral to the sigmoid should not be used. The peritoneal sac is mobilized medially on both sides. The ureter continues to be located extraperitoneally, it should be noted that it can be displaced during exposure, because it adheres to the peritoneum. The ureters are mobilized with sufficient periureteral adventitia in an ascending fashion on both sides (Figure 37.3B). A plane is established between the ureter and the lateral pedicles of the bladder. As the ureter and bladder are retracted

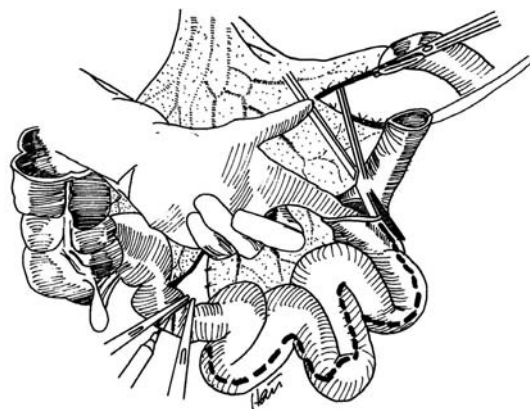


Figure 37.4 Selection of the ileal segment 25–30 cm away from the ileocecal valve, with an appropriate vascular supply and antimesenteric incision of ileum except for the small chimneys on both sides of the 'W' and the intended site of the ileo-urethral anastomosis (interrupted line).

medially, the lateral pedicle is exposed. Finally, the ureter is clamped distally. Fine traction sutures are inserted in the proximal surface of the ureter, and it is divided against the clamps. Then, the ureter is dissected proximally so that about 6–9 cm is free.⁴

PREPARING THE LOOP

The light behind the mesentery should be adjusted to select a 65 cm long ileal segment 20–25 cm proximally from the ileocecal valve. Spasticity of the bowel or a thick short mesentery may lead to the use of more bowel than necessary, thus increasing the reservoir capacity. It is helpful to place two temporary stay sutures at the intended resection lines. They can be moved several times if necessary. The most dependable part of the segment should be long enough to reach the top of the symphysis pubis in the skin level, this point should be marked with a suture. This maneuver guarantees that the reservoir will reach the urethra without difficulty. The distal division of the mesentery along the avascular region between the ileocolic artery and the terminal branches of the superior mesenteric artery should extend to the base of the mesentery to provide maximum mobility and sufficient length to reach the urethra. The proximal incision of the mesentery is made as short as possible to provide maximum vascular supply to the ileal segment. The ileum is then divided between bowel clamps. A standard bowel anastomosis is performed, and the mesenteric trap is closed. The isolated bowel segment is thoroughly cleaned or rinsed with saline or an iodine solution (Figure 37.4).⁴

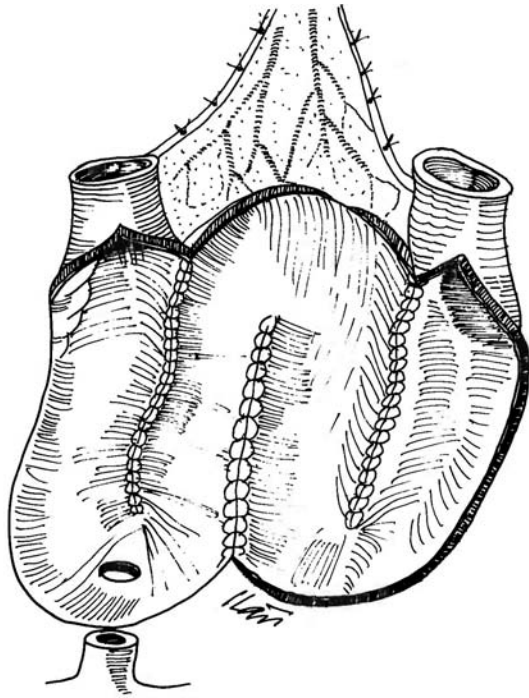


Figure 37.5 'W' shaped reconfiguration of the intestinal segment after detubularization and asymmetric incision of the ileal wall at the site of the anastomosis to the urethra, forming a 'U' shaped flap. Note that the distance between the chimneys must be at least 7–8 cm to avoid strangulation and to allow for tension-free closure of the reservoir.

CONSTRUCTION OF THE RESERVOIR

Four lengths of ileum are arranged in the shape of a 'W' with 3 cm chimneys on each side of the 'W' using five to six Babcock clamps or traction sutures. Other than the chimneys, the bowel is opened at the antimesenteric border except for a 5–7 cm section centered around the marking suture, which is opened close to the antimesenteric border to create a 'U' shaped flap. At a distance of 2–3 cm from the tip of that flap, a buttonhole of all layers is excised from the ileal plate. An ileal plate is formed by sewing together the cut edges of the antimesenteric borders of the 'W' using 2-0 vicryl on a straight needle (Figures 37.5 and 37.6).⁴

ILEOURETHRAL ANASTOMOSIS

A 22 Fr catheter is placed through the buttonhole. For the actual anastomosis, six previously placed double-armed sutures using 3-0 vicryl in the urethra are used. The inner sutures are passed through the neobladder outlet in the ileal plate without grasping the ileum, and the corresponding outer sutures grasp the entire ileal wall 5–8 mm lateral to the neobladder outlet (Figure 37.7).

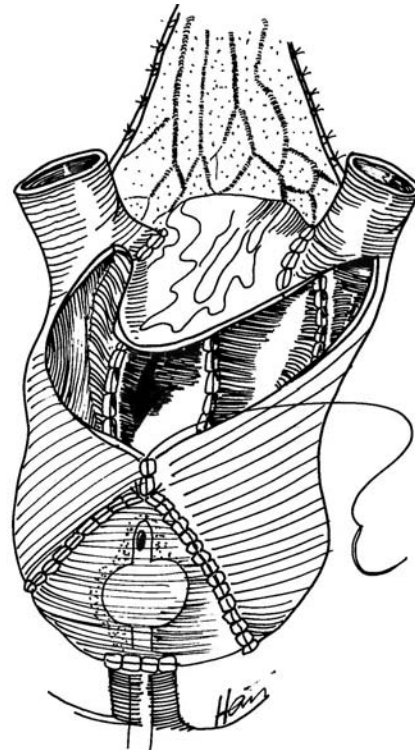


Figure 37.6 Closure of reservoir. Note the ample size of ileum flap between chimneys to allow for easy closure of reservoir.

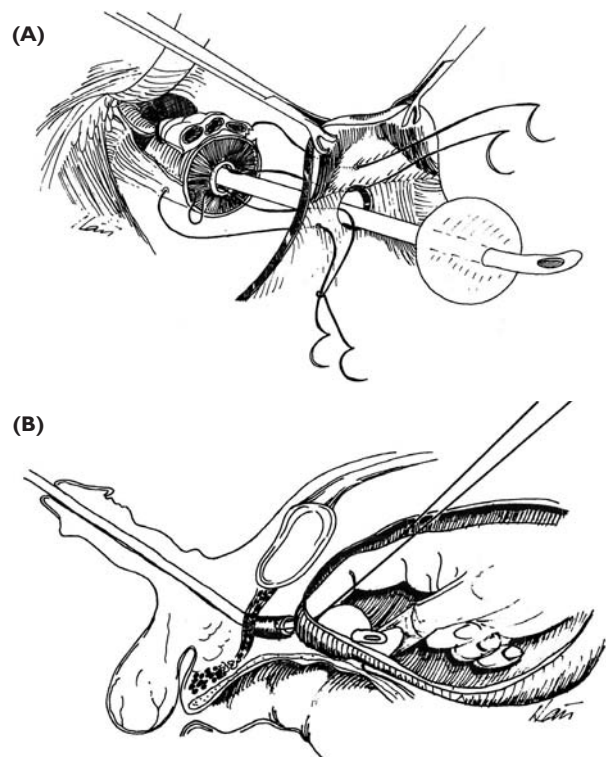


Figure 37.7 (A) Ileourethral anastomosis, anterior view. (B) Lateral aspect of the ileourethral anastomosis. The sutures are tied from inside the ileal bladder. Alternatively the anastomosis can be done in the same fashion as in radical prostatectomy, i.e. from outside.

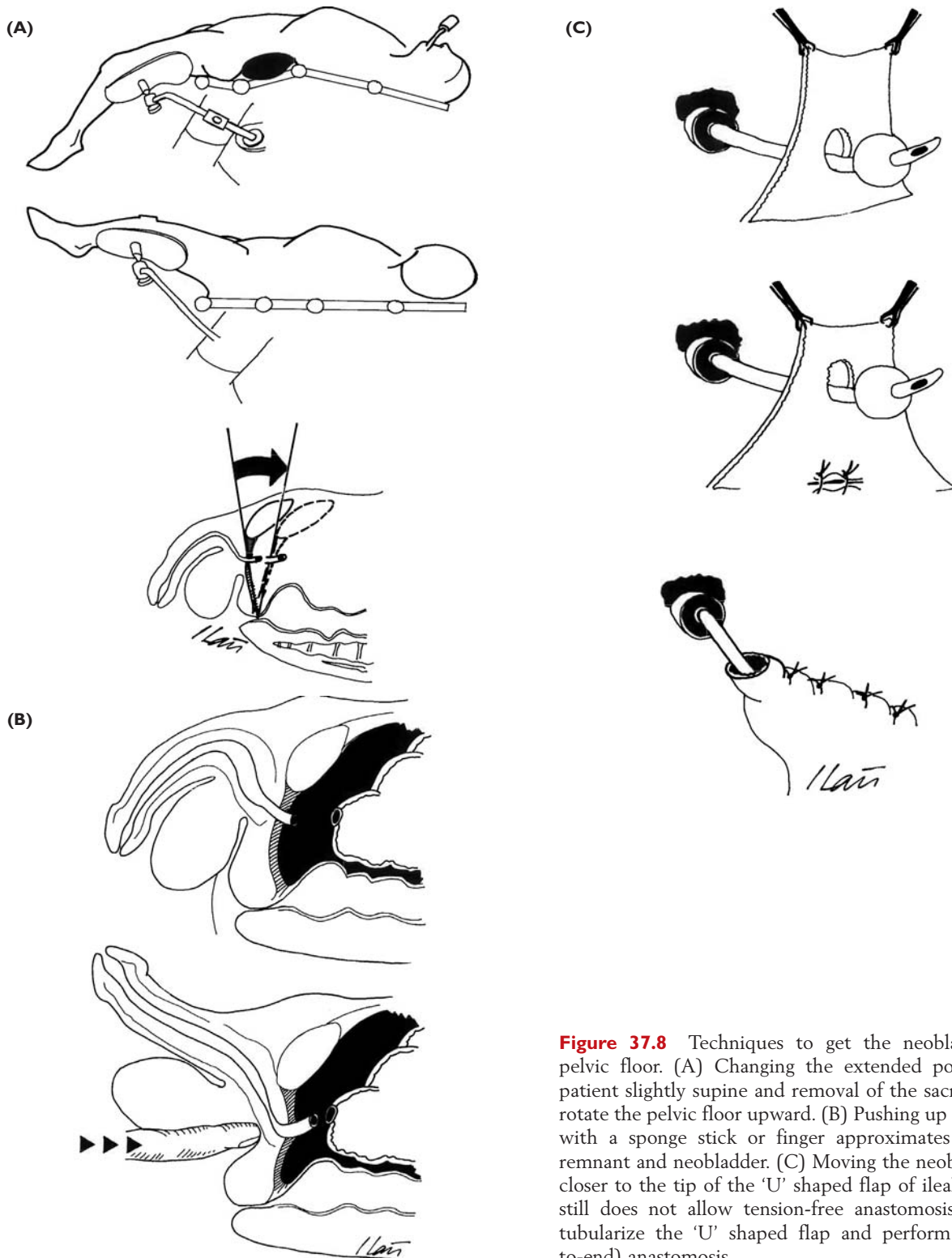


Figure 37.8 Techniques to get the neobladder to the pelvic floor. (A) Changing the extended position of the patient slightly supine and removal of the sacral cushion to rotate the pelvic floor upward. (B) Pushing up the perineum with a sponge stick or finger approximates the urethral remnant and neobladder. (C) Moving the neobladder outlet closer to the tip of the 'U' shaped flap of ileal plate. If this still does not allow tension-free anastomosis, one should tubularize the 'U' shaped flap and perform direct (end-to-end) anastomosis.

This guarantees a wide, ideal, funnel-shaped anastomosis so that mucosa is in direct contact with urethral epithelium. Next, under gentle traction on the transurethral catheter, the ileal plate is manipulated down to the urethral remnant, and the knots are inside the bowel (Figure 37.7). The cut edges of the 5–7 cm 'U' shaped flap are sewn together over the

22 Fr catheter. The lower third of the anterior wall of the neobladder is closed, beginning inferiorly with interrupted 3-0 vicryl (Figure 37.6).

In 10% of patients, the ileourethral anastomosis may cause some difficulties. In which case, some or all of the following techniques are helpful to overcome this dilemma (Figure 37.8): loosening the retractor,

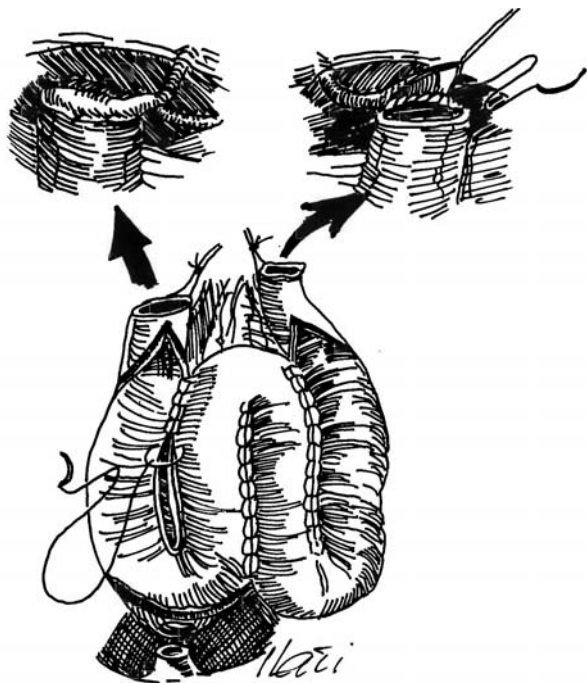


Figure 37.9 Refluxing ileoureteral anastomosis using chimneys of a 3 cm afferent limb on each side.

straightening the operating table, removing the sacral cushion, neutralizing the extended position of the patient, bringing up the perineum with a sponge stick, freeing the cecum and descending colon as in retroperitoneal lymph node dissection (RPLND), moving up the neobladder outlet to the tip of the 'U' shaped flap, or performing an end-to-end anastomosis after tubularization of the 'U' shaped flap. Any incisions into the mesentery of the neobladder should be avoided. The neobladder mesentery should not be pulled roughly to the pelvic floor.⁴

REFLUXING ILEOURETERAL ANASTOMOSIS

On each side, the ureters are trimmed as appropriate for their chimney (Figure 37.9). The ureterointestinal anastomosis can be done extraperitoneally above the common iliac vessels using a Bricker or Wallace (our choice) technique without competing with the bowel mesentery for an anastomotic site.

This part of the procedure is facilitated when the distance between the two chimneys is 7–10 cm. This chimney modification simplifies and enhances the flexibility of the procedure. This provides two major advantages: extra length for the neobladder to reach the distal ureteral stumps because of an ileal chimney;

simplified abdominal or flank access to the postoperative ureterointestinal anastomosis should the patient require reoperation for ureterointestinal anastomosis allowing antirefluxing and refluxing anastomotic techniques.^{2,4}

EXTRAPERITONEALIZATION OF THE ENTIRE NEOBLADDER INCLUDING THE ILEOURETERAL ANASTOMOSIS

Using the two large peritoneal flaps from visceral pelvic peritoneum, extraperitonealization of the entire neobladder including the ileoureteral anastomosis can easily be achieved. Both flaps are sewn together, except for the portion where the mesentery of the neobladder runs through them. The peritoneal cavity is closed in a standard fashion. Alternatively, the flaps can be sewn to the posterior wall of the neobladder (Figure 37.10).

After placing appropriate ureteral stents, they are brought through the anterior neobladder suture line. The remaining anterior neobladder wall is closed in a 'T' shape with running 3-0 vicryl. No cystostomy tube is placed. Two 20 Fr silicone drains are placed into the small pelvis.⁴

POSTOPERATIVE CARE

The transurethral catheters need to be flushed and aspirated with saline every 6 hours. This is mandatory to prevent any mucus formation and catheter blockage that may lead to bladder rupture. This risk is highest when bowel activity returns and the catheter is still in place. The return of bowel function should be accelerated with parasympathomimetic medications (e.g. neostigmin three to six times 0.5 mg per cut) and in smokers with nicotine patches.²

If the cystogram on postoperative day 14 excludes any urinary extravasation the left ureteral stent is removed first, followed 24 hours later by the right stent. The urethral catheter is removed between days 18 and 21. A urine sample should be sent for culture at the time the catheter is removed. Any urinary tract infection must be treated. The patient is instructed to void in a sitting position every 2 hours during the day and every 3 hours with the help of an alarm clock at night. Voiding needs to occur by relaxation of the pelvic floor, followed by only slight abdominal straining. This may be aided by hand pressure on the lower abdomen and bending forward. Effectiveness of emptying needs to be

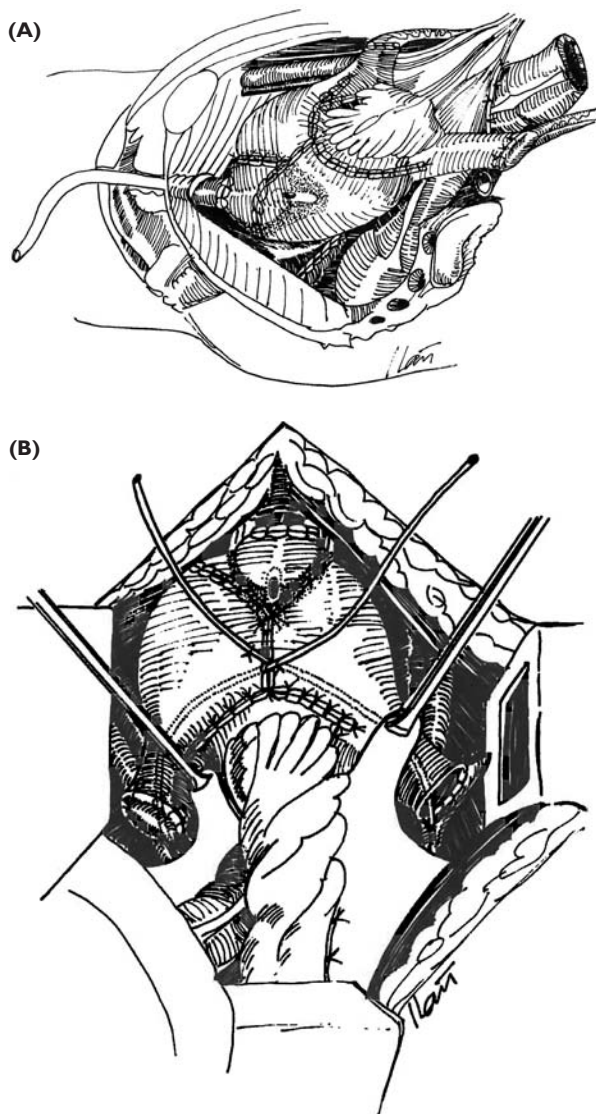


Figure 37.10 (A) Final situation. Neobladder on top anterior vaginal wall. Ileoureteral anastomoses above common iliac vessels. Left ureter courses lateral to sigmoid in its physiologic bed. Extraperitonealization of neobladder to follow. (B) Completely extraperitoneal localization of neobladder as well as ileourethral and ileoureteral anastomoses.

monitored with ultrasound of the reservoir. The voiding interval is gradually increased from every 2 to 4 hours. The patient must not void prior to the allotted time period even if dribble incontinence ensues, aiming for a gradually distended bladder capacity of 500 ml, with improved continence.²

COMPLICATIONS

Regaining continence depends also on counseling sphincter training, age of the patient, and surgical technique

with nerve preservation to urethra and pelvic floor. Sphincter training is taught by doing a digital rectal examination and requesting contraction of the sphincter ani only. The patient performs this ten times per hour, maintaining contraction for 6 seconds. Once continence is achieved on a daily basis. Postmicturition dribble incontinence can be avoided by instructing the patient to milk the urethra at the end of micturition.

Hypercontinence primarily occurs with female bladder substitutes. This can be reduced by having an unobstructed outlet with prevention of kinking of the urethra or reservoir. Preserving the autonomic nerve supply to the proximal third of the urethra will maintain its tubular shape. If denervated, a flaccid, hypotonic urethra results that has the tendency to kink. If in doubt of the proper innervation, resection of the proximal third of the urethra is advisable. However, this may end up in dribble incontinence when walking due to a short urethra. The pudendal nerve still innervating the distal urethra and pelvic floor will usually maintain continence at times of sudden increased abdominal pressure.

Following catheter removal there is an increased risk of metabolic acidosis, in particular in the presence of residual urine. This is the most frequent undiagnosed complication following bladder substitution. One must be aware of the potential symptoms that may arise with metabolic acidosis. The base excess should be monitored with venous blood gas analysis every other day. Base excess needs to be corrected if negative. This is usually done with sodium bicarbonate 2–6 g/day. Another cause of metabolic acidosis is hypovolemia due to excess salt loss. These patients have a rapid drop in body weight due to dehydration and anorexia. Daily body weight monitoring is essential in the postoperative period. Patients should consume 2–3 liters of fluids per day, which needs to be supplemented with increased salt intake in their diet to prevent salt losing syndrome.

CONCLUSIONS

The major benefit of the neobladder is the ability to void without a catheter, but at a small risk of being incontinent. Of course, other factors affecting the patient and surgeon may supersede these guidelines. The surgeon's preference, length of surgery, ease of construction, potential need for stomal revision, the patient's body image, and other characteristics of the patient are among the factors that must be considered when choosing which continent urinary diversion to provide to each individual patient.

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38 Ileal orthotopic bladder substitution

Nivedita Bhatta Dhar and Urs E Studer

INTRODUCTION

The type of orthotopic bladder substitute presented here is a low pressure, high compliance reservoir which achieves continence and preserves renal function while also avoiding fluid and electrolyte imbalances. In this chapter we describe the surgical technique to construct an ileal orthotopic bladder substitute combined with an afferent tubular segment.

The length of resected ileum is relatively short and since both the terminal ileum and ileocecal valve are left intact, the risk of associated intestinal malabsorption is reduced. A low pressure system is generated because the reservoir is constructed from a double folded ileum that is transected along its antimesenteric border, thereby resulting in bowel wall contractions that are asynchronous and uncoordinated. Furthermore, as illustrated by Laplace's law (pressure = tension/radius), intraluminal pressure is low for a given tension because the conversion of a tubular structure into a spherical reservoir increases the radius. The spherical shape can achieve maximal capacity while the surface: volume ratio limits the reabsorbing surface and thereby minimizes associated metabolic issues.

The 14–16 cm afferent tubular limb allows for the ureters to be resected at a safe oncologic distance from the bladder as well as removal of peri-ureteral lymphatics which may harbor micrometastasis. In addition, ureteral ischemia is precluded and thereby subsequent stricture formation. The segment's isoperistaltic contractions help prevent ureteral reflux and transmission of reservoir pressure into the renal pelvis. Also, in the event of tumor recurrence, the afferent limb can easily be converted into an ileal conduit.

PATIENT SELECTION

Orthotopic diversion may now represent the procedure of choice in the properly selected patient undergoing cystectomy. However, as with all bladder substitutes, the cancer operation must not be compromised by the orthotopic reconstruction. In addition, the external rhabdosphincter and internal lissosphincter complex and corresponding innervations must be functionally intact.

Table 38.1 Patient selection criteria for continent urinary diversion

Non-metastatic disease
Negative biopsies from prostatic urethra (male)/bladder neck (female)
Adequate renal function (serum creatinine <1.5 mg/dl)
Normal liver function
No active inflammatory bowel disease or previous extensive bowel resection
Physical and mental ability to live with a bladder substitute
Compliance to routine follow-up

As is true for all bladder substitutes, specific criteria for selection are related to the disease stage, and renal and liver function, as well as to the patient's willingness to comply with routine follow-up. These criteria are summarized in Table 38.1. Adequate renal function as defined by serum creatinine less than 1.5 mg/dl precludes the need for lifelong bicarbonate supplementation. The ileal orthotopic bladder substitute is also particularly well suited for patients in whom the sequelae of ileocecal resection would be avoided.

PREOPERATIVE PATIENT PREPARATION

Preoperatively, patients eat a regular diet until the evening before surgery when they consume only a light meal. Bowel preparation is accomplished with two enemas given late in the afternoon before the day of surgery. Antegrade rinses of the bowel and neomycin-erythromycin intestinal preparations are avoided. Such preparations can increase the risk of fluid imbalances. In the elderly patient, this can produce cardiovascular instability due to intravascular volume depletion as well as potentially placing the patient in a catabolic state even prior to surgery. All patients receive perioperative and postoperative prophylactic antibiotics and subcutaneous heparin is administered in the arm the evening before surgery and continued postoperatively. In addition, to prevent a deep venous thrombosis and pulmonary issues, patients are taught appropriate exercises by a physical therapist and given pneumatic stockings.

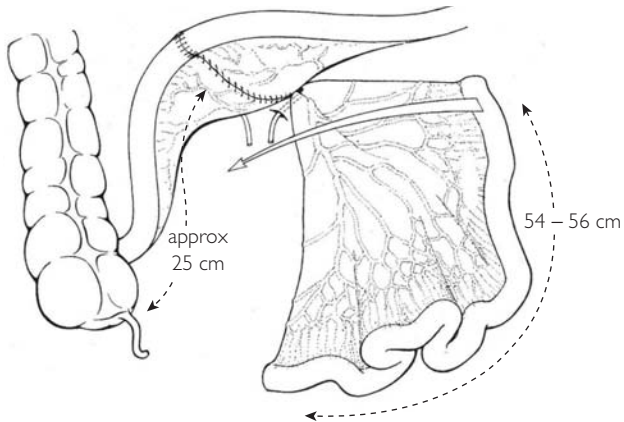


Figure 38.1 55 cm of ileum isolated 25 cm proximal to the ileocecal valve.

OPERATIVE TECHNIQUE

Under general and epidural anesthesia, the latter placed for postoperative pain control, the patient is placed in a dorsal Trendelenburg position with overextension of the pelvis for optimal operative exposure. On the operative field, an 18 Fr Foley catheter is introduced into the bladder. The approach is through a lower midline incision. The technique of en bloc radical cystectomy with bilateral pelvic lymphadenectomy has been described elsewhere.

Preparation of the ileal segment for the neobladder

The bladder substitute is performed by isolating 55 cm of ileum, 25 cm proximal to the ileocecal valve (Figure 38.1). The ileocecal valve and the most distal 25 cm of ileum are preserved in order to reduce the risk of vitamin B12 malabsorption/loss and increased bile acid loss due to decreased transit time. One hour prior to bladder substitute construction, analgesic administration via the epidural is ceased. This prevents increased muscle tone and activity which would result in an artificial shortening of bowel and thereby potential to remove more bowel than is required for pouch reconstruction. The ileum used for bladder substitute construction is measured with a 10 cm ruler along the mesoileum and without over stretching of the bowel.

The distal mesenteric division which is essential for adequate mobility of the reservoir should extend deep into the mesentery. The proximal mesenteric division, however, is short and ensures a broad vascular blood supply to the bladder substitute by at least two

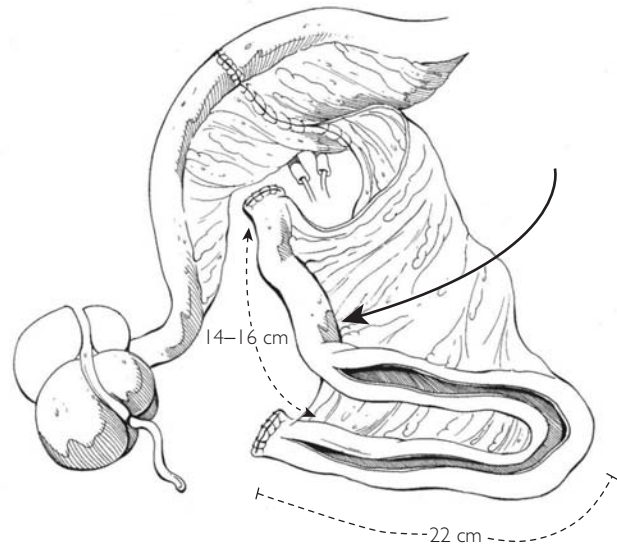


Figure 38.2 Proximal afferent segment and opened distal 45 cm segment.

separate vascular arcades. To re-establish bowel continuity, a standard small bowel anastomosis is performed end-to-end with a running (4-0 Vicryl) suture through the seromuscular layers. This same technique is employed for closure of both ends of the ileal segment. The mesenteric gap is then closed. The harvested ileum is divided between the proximal afferent segment and the distal 42–45 cm segment that will form the reservoir portion of the bladder substitute. This distal part of the ileal segment is then opened with scissors along the antimesenteric line (Figure 38.2).

Ureteroileal anastomosis

The left ureter is mobilized up to the lower pole of the kidney with care, to maintain its surrounding blood supply and thereby prevent ischemia. It is then brought without tension to the right side of the abdomen retroperitoneally by crossing the aorta slightly above the inferior mesenteric artery. Note that if the ureters need to be resected close to the kidney (e.g. carcinoma in situ, compromised vascular supply, previous radiation history), a longer afferent ileal segment can be harvested to bridge the necessary distance.

The ureters are anastomosed in an end-to-side fashion to the proximal (non-incised) afferent tubular portion of ileum. The ureteral ends are then spatulated over a length of 2 cm. The anastomoses are placed paramedial to the antimesenteric border at the most proximal portion of the afferent tubular segment. To prevent bowel ischemia between the ureteral

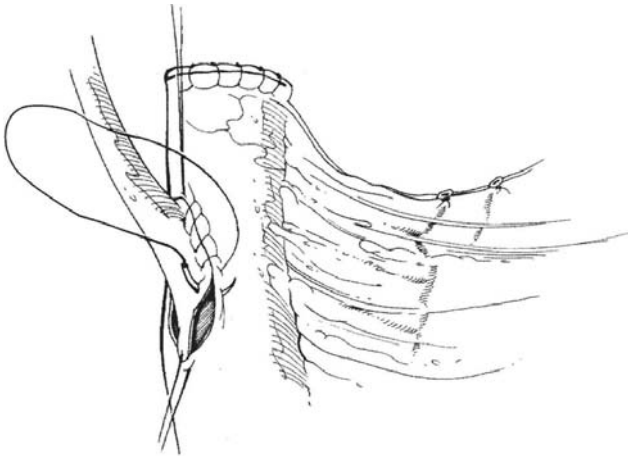


Figure 38.3 Ureteroileal anastomosis.

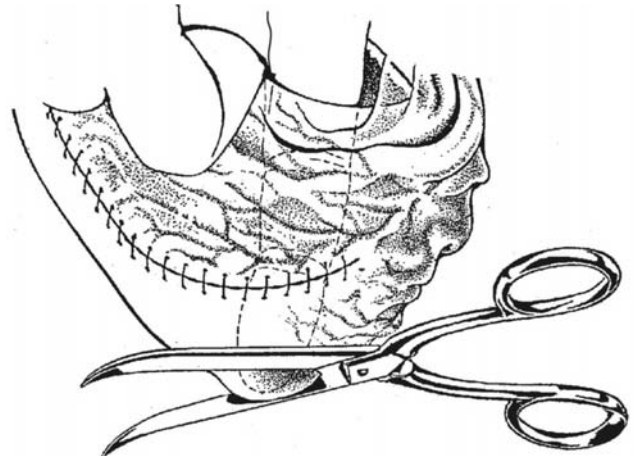


Figure 38.5 Surgeon's finger is introduced to determine the most dependent part and a 1 cm diameter hole is excised.

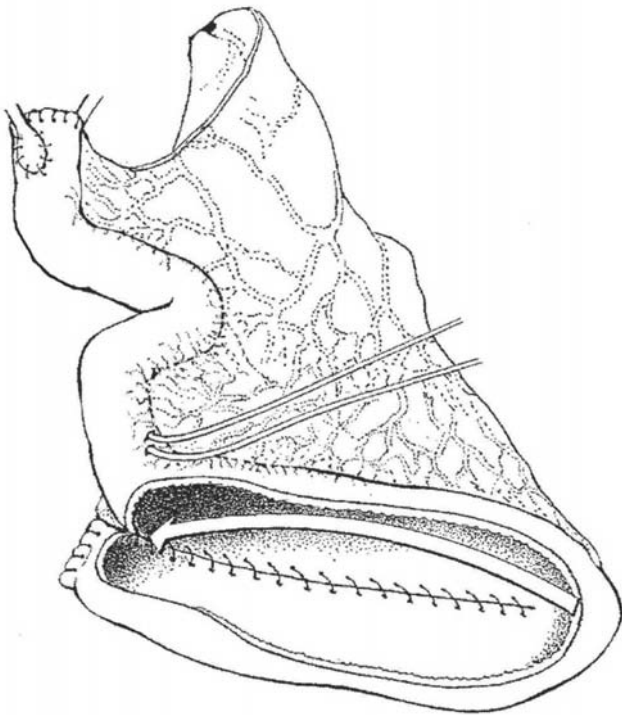


Figure 38.4 Bottom of the U is folded up between the two sides of the U.

anastomosis, the right ureter is placed approximately 1 cm distal to the left ureter.

After placing a suture (4-0 polyglycolic acid) at each end of the spatulated ureter and ileal incision, the anastomosis is performed using the Nesbit technique. To prevent a fistula resulting from ureteral mucosal prolapse and to establish a watertight anastomosis, special care should be taken to have the ureteral wall lie between the mucosa and seromuscularis of the bowel. This is accomplished by starting each anastomosis on the ureteral wall. At the proximal angle, with running

4-0 Vicryl suture, a minimal amount of ureteral wall tissue is anastomosed to the seromuscular layer of bowel so as to prevent narrowing of the ureter. Gradually the amount of ureteral wall tissue incorporated increases in order to secure the anastomosis.

Prior to completion of the anastomosis each ureter is stented with an 8 Fr ureteral catheter which is secured with 4-0 Vicryl Rapid (Ethicon, Hamburg, Germany) through the wall of the ureter and stent, and loosely tied so as to prevent ischemia. Tension on the anastomosis is avoided with three interrupted sutures placed between the distal peri-ureteral tissue and the afferent tubular segment. In doing so, the peri-ureteral tissue also covers the suture line. The stents are then passed through the distal tubular segment wall where their exit sites are covered with mesenteric fat so as to prevent urine leakage when they are removed (Figure 38.3).

BLADDER SUBSTITUTION CONSTRUCTION

The previously opened portion of the ileal segment is folded into a 'U' shape (Figure 38.2) and the two medial borders are sewn together at the seromuscular layers with running 2-0 Vicryl suture. The bottom of the U is folded up between the two sides of the U forming a sphere shaped reservoir (Figure 38.4). This effectively creates a low pressure spherical shaped reservoir with an initial capacity of approximately 120 ml. Prior to final closure of the reservoir, the surgeon's forefinger is introduced to determine its most dependent part and a 1 cm diameter hole is excised from the wall as shown in Figure 38.5. Importantly, although it may appear

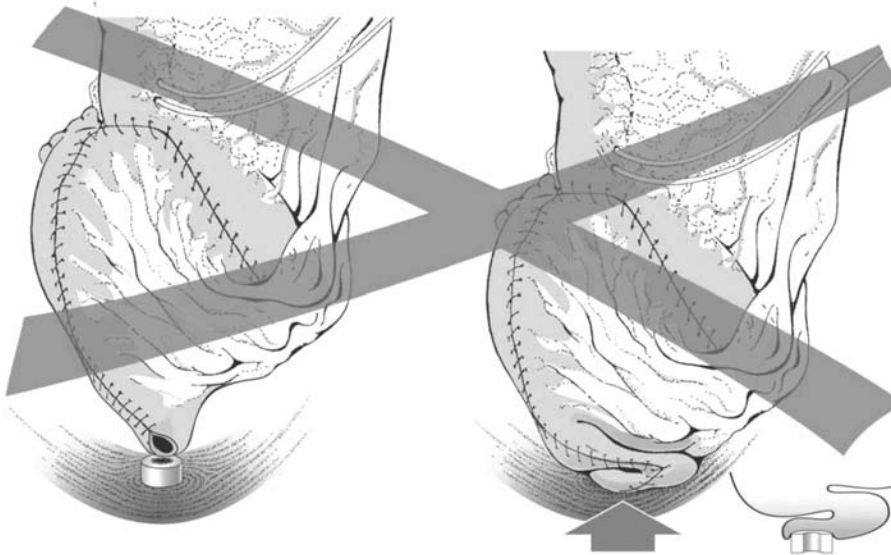


Figure 38.6 Anastomosis of the urethra to the neobladder is not made to the funnel shaped end of the reservoir.

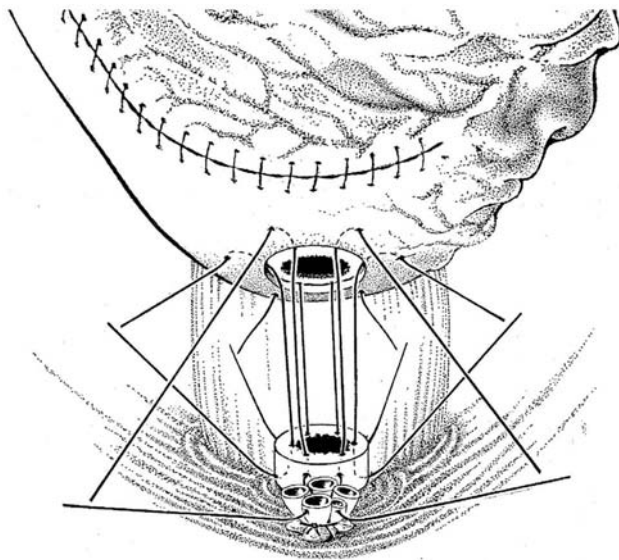


Figure 38.7 Six 2.0 Vicryl sutures anastomose the previously made hole in the bladder substitute to the urethra.

easier to perform, it is imperative that the anastomosis of the urethra to the neobladder is not to the funnel shaped end of the reservoir. This error would increase the risk of kinking and obstruction at the anastomosis site when the reservoir is full (Figure 38.6). To achieve optimal voiding, the anastomosis must sit broadly on the pelvic floor.

After placement of a silicone 18Fr Foley urethral catheter, six 2-0 Vicryl sutures anastomose the previously made hole in the bladder substitute to the urethra (Figure 38.7). Two posterior sutures are passed

through Denonvillier's fascia, two laterally through the urethra and two anteriorly, taking only a little of the urethra but also through the ligated Santorini's plexus. When placing the urethrointestinal sutures, the needle incorporates 3–4 mm of the sphincter but exits at the mucosal edges, thereby bringing the two mucosal edges close together and maximizing urethral length as well as reducing the incidence of anastomotic strictures. If necessary, the operating table is now flexed in order to reduce the distance between the bladder substitute and the urethra. In situations where the mesentery is short and the anastomosis between the reservoir and urethra is under tension, careful superficial incisions of the neobladder mesentery will provide for further length. Sutures are loosely tied to prevent cutting, ischemia, and stenosis. Rarely, to prevent undue traction on the anastomosis, two stitches placed lateral to the urethra can fix the bladder substitute to the pelvic floor. Before complete closure of the reservoir, a cystostomy tube is passed through the bladder substitute wall and its exit site is covered with mesenteric fat (Figure 38.8).

SURGICAL MODIFICATIONS FOR OBESE PATIENTS

An ileal neobladder can successfully be constructed and brought down into the pelvis of obese patients. A measure of whether the reservoir will work in obese patients, is if the bowel at 12 cm from the distal harvested end is able to reach the base of the penis. To ensure this will

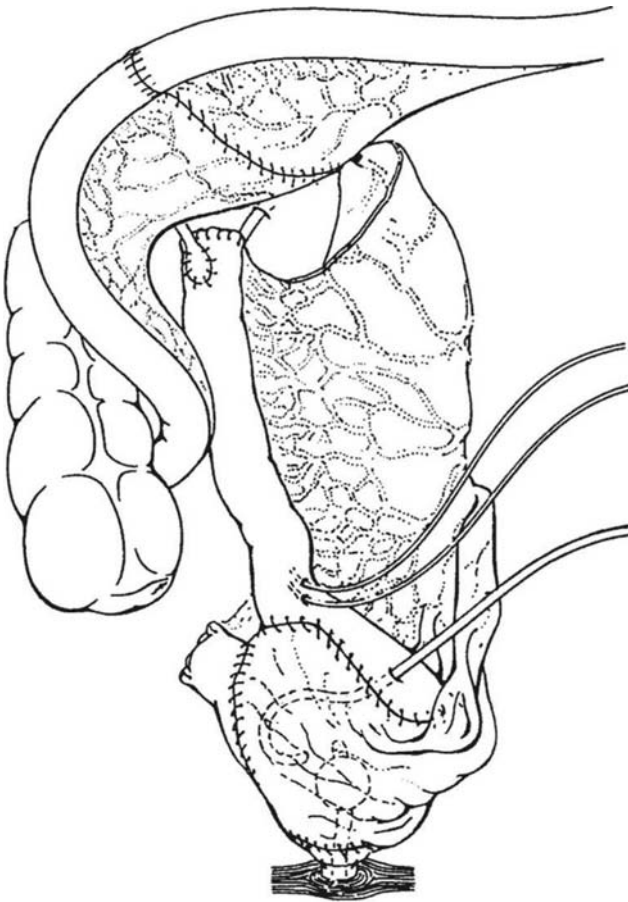


Figure 38.8 Closed reservoir with a cystostomy tube.

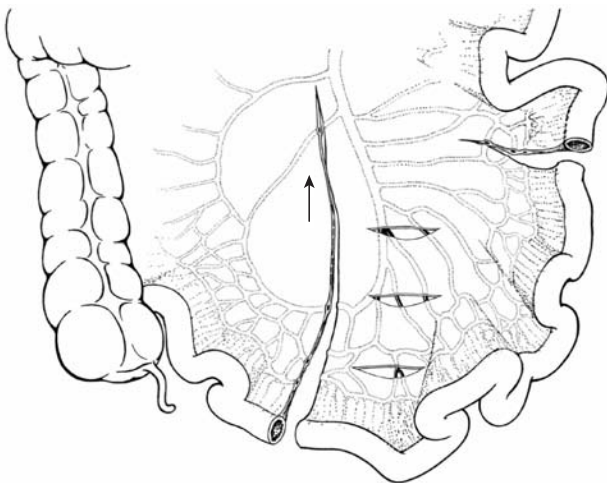


Figure 38.9 The distal mesenteric division is extended deeper into the mesentery.

happen the following steps should be employed. First, extend the distal mesenteric division deeper into the mesentery, this will provide for increased mobility

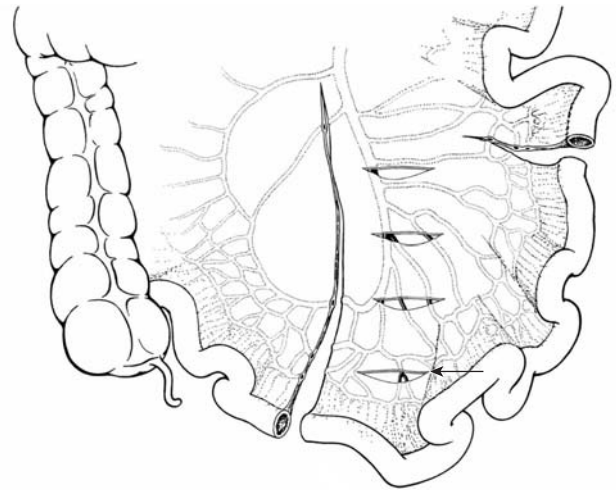


Figure 38.10 A vessel proximal to Riolo's arcade is transected.

(Figure 38.9). In addition, unflex the operating table as much as possible and if necessary make superficial transverse incisions of the serosa. If there is still tension, then 12 cm from the distal end, transect a vessel proximal to Riolo's arcade (Figure 38.10). Provided collateral vessels are left on either side, this will not compromise vascular supply to the reservoir.

POSTOPERATIVE CARE

Critical components to good long-term results include the ability to create a high compliance, low pressure reservoir with an adequate continence mechanism as well as patient compliance and meticulous postoperative care.

Ureteral stents are removed 4–7 days after surgery. At 8–10 days postoperatively and after pouchography documents no evidence of urinary leakage, the cystostomy tube is removed. The Foley catheter remains for an additional 2 days so as to provide adequate time for closure of the cystostomy tube exit site from the reservoir wall. Although our patients are on antibiotics, all drains are removed as early as possible to prevent infections. After the patient is drain free, any bacteriuria is treated with antibiotics until the urine is sterile.

Patients are carefully instructed on how to void. Initially, they are taught to empty the pouch every 2 hours during the daytime in a sitting position by relaxing the pelvic floor and increasing intra-abdominal pressure. At night, they are instructed to use an alarm clock to void every 3–4 hours. Initially, the urine is often hypo-osmolar and, consequently, the bladder substitute will secrete sodium chloride resulting in a salt losing

syndrome and thereby hypovolemia and metabolic acidosis. To prevent this series of metabolic events, patients are instructed to consume 2–3 liters of liquids a day, to increase salt intake and are prophylactically placed on sodium bicarbonate (2–6 g/day) after ureteral stent removal. These patients are carefully followed with regular assessments of blood gases and body weight.

Patients without metabolic acidosis (no negative base excess) or those managed appropriately with oral intake of sodium bicarbonate are instructed to retain urine for 3 and later for 4 hours in order to obtain a bladder capacity of up to 500 ml. During this exercise, increased pouch pressures may result in incontinence, but the elevated pressures are essential to increase the reservoir's capacity. Therefore, patients are advised to not void when they experience such incontinence, otherwise the bladder substitute will never achieve the desired capacity.

With increasing capacity, night-time continence will improve but on the other hand, a reservoir capacity of greater than 500 ml should be prevented. Over distention of the reservoir will result in a floppy pouch unable to adequately empty, increased residual urine, and the potential for urinary retention. Residual urine should be monitored, recognized early, and promptly managed. The cause of residual urine needs to be addressed (urethra cystoscopy) and any evidence of outlet obstruction needs to be incised or resected. In addition, bacteriuria should also be appropriately treated. Our patients are followed regularly at every 6 months for 5 years and then at yearly intervals.

COMPLICATIONS

We recently published our 20 years' experience with the ileal neobladder. In our experience, early diversion related complication (within 30 days) occurred in

13% of patients. Pyelonephritis was the predominant complication noted (5.8%). Diversion related late complications (more than 30 days) requiring re-hospitalization were metabolic acidosis, pyelonephritis, and sepsis in 4.4%, 3.9%, and 2.1%, respectively, and urinary retention due to infection and consequent mucus production in 4.5%. Typical late complications requiring surgery were bladder substitute outlet obstruction in 12% and incisional or inguinal hernias in 10%.

EXPERIENCE WITH THE TECHNIQUE

After 20 years' experience and a median follow-up of 32 months in 482 patients, our results are promising. In this series, 93% of patients could void spontaneously at the last visit, and 90% had daytime and 78% night-time continence with 3–4 hour voiding intervals. The remaining 7% were on intermittent self-catheterization or had an indwelling catheter for nursing home reasons. In addition to performing the above detailed surgical technique, success with this method of substitution demands meticulous postoperative care and follow-up.

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39 Ileal neobladder: T-pouch

John P Stein

INTRODUCTION

The goals of urinary diversion have evolved from simply diverting the urine and protecting the upper urinary tracts. Contemporary objectives of urinary diversion should also include a form of reconstruction which provides a safe and continent means to store and eliminate urine, with efforts to improve the quality of life of the individual.¹ Currently, four reasonable options regarding lower urinary tract reconstruction exist: an incontinent cutaneous diversion, the ileal or colon conduit; a continent cutaneous reservoir, requiring catheterization of a cutaneous stoma; a continent rectal reservoir, with storage and elimination of urine via the rectum; and the orthotopic bladder substitute (neobladder), with reconstruction to the native intact urethra.

The evolution of urinary diversion and lower urinary tract reconstruction over the past 60 years has been remarkable. Progress in lower urinary tract reconstruction should be not only attributed to advances in medical and surgical improvements, but also credited to thoughtful and creative surgeons looking to improve upon existing forms of urinary diversion. In 1950, Bricker introduced the ileal conduit which established a technically simple and reliable form of urinary diversion.² The ileal conduit remains even today a commonly performed urinary diversion and a standard to which other forms of urinary reconstruction are compared. Concurrent with Bricker's introduction of the ileal conduit, Gilchrist et al independently reported on a continent cutaneous form of diversion utilizing the ileocecal valve as the continence mechanism, and the terminal ileum as a catheterizable stoma.³ For various medical reasons, Gilchrist's ileocecal reservoir garnered little support, while the technically simpler Bricker ileal conduit became the urinary diversion of choice for the next several decades.

The concept of a continent cutaneous urinary diversion was eventually reintroduced and popularized in the early 1980s at several large academic institutions.⁴⁻⁶ These experiences revolutionized urinary diversion to a continent cutaneous form of diversion. Although patients were relieved from the issues of an external collection device, catheterization of the continent abdominal stoma was required. The continent cutaneous urinary diversion was considered a step

forward and an improvement upon the standard ileal or colon conduit. These continent reservoirs, however, are technically more challenging, take significantly longer to construct, and are associated with a reoperation rate, particularly the efferent catheterizable limb. Despite the benefits of the continent cutaneous reservoir over an ileal conduit, the aforementioned issues even today have limited the widespread application of this form of urinary diversion.

A natural progression of the continent cutaneous urinary diversion was the orthotopic bladder substitute (neobladder) connected directly to the native intact urethra. The orthotopic neobladder resembles the original bladder in location and function. An orthotopic form of reconstruction eliminates the need for a cutaneous stoma and a cutaneous collection device and relies on the patients' intact rhabdosphincter continence mechanism (external striated sphincter muscle); eliminating the need for intermittent catheterization in most cases and the efferent limb of the continent cutaneous reservoir which may require revisional surgery. Voiding is effectively accomplished by concomitantly increasing intra-abdominal pressure (Valsalva) with relaxation of the pelvic floor musculature.

Orthotopic reconstruction was initially applied to carefully selected male patients in the mid-1980s with excellent clinical and functional results.⁷ The positive experience in men subsequently stimulated interest in applying orthotopic reconstruction to women.⁸ Based on neuroanatomic dissections⁹ which provided a better understanding of the continence mechanism in women, as well as defined pathologic guidelines,¹⁰ which allowed for proper patient selection from a cancer perspective in women, orthotopic reconstruction was subsequently and successfully applied to women in the early 1990s. The majority of both male and female patients undergoing cystectomy today are appropriate candidates for orthotopic reconstruction.¹

From 1982 to 1997, the primary form of urinary diversion at the University of Southern California (USC) was the continent Kock ileal reservoir (Kock pouch) as described by Kock et al.⁶⁻⁸ The intussuscepted nipple valve provided the continence and antireflux mechanism in the Kock ileal reservoir. The principles of the continent Kock ileal reservoir (cutaneous and orthotopic form) are sound; however,

complications can occur.^{11–13} Most complications associated with the Kock ileal reservoir relate to the intussuscepted limb, either the antireflux (afferent limb) or the continent catheterizable (efferent limb) nipple.^{12,13}

A review of our large experience at USC with the Kock ileal reservoir, revealed a 10% complication rate associated with the afferent intussuscepted antireflux nipple in over 800 patients (including the continent cutaneous and orthotopic Kock ileal reservoir).¹² The three most common complications associated with the intussuscepted afferent nipple include stone formation (associated with exposed staples that secure the afferent nipple valve) in 5%, afferent nipple stenosis (thought to be caused by ischemic changes resulting from the mesenteric stripping required to maintain the intussuscepted limb) in 4%, and extussusception (prolapse of the afferent limb) in 1% of patients. Although the majority of these afferent nipple valve complications (60%) can be managed with endoscopic techniques, nonetheless, may result in some morbidity. Approximately 3% of all patients undergoing a continent Kock ileal reservoir will require an open surgical revision to repair an afferent nipple complication.¹²

The need to improve upon the intussuscepted Kock nipple valve became increasingly obvious. Based on reports from Ghoneim's group in Mansoura, Egypt employing a ureteral serous-lined, extramural tunnel,^{14,15} as well as our initial experience with the Mitrofanoff appendiceal subserosal tunnel at USC, we subsequently developed our initial experience with a flap-valve technique called the 'T-mechanism'.¹⁶ The T-mechanism is a versatile technique that can be applied as an antireflux mechanism, as well as a continent mechanism in a cutaneous reservoir.¹⁷ Since 1997, we have utilized the T-mechanism as an important modification to the Kock ileal reservoir.^{16,18}

The T-mechanism was first successfully incorporated as the afferent antireflux limb of an orthotopic reservoir (T-pouch)^{16,17} and, subsequently, into an afferent antireflux and efferent continence limb of a cutaneous reservoir (double-T-pouch) soon after.¹⁸ We believe the flap-valve T-mechanism has eliminated the complications associated with the intussuscepted nipple valve, while maintaining an effective antireflux or continence mechanism. The surgical technique of the orthotopic T-pouch ileal neobladder is described below.

SURGICAL TECHNIQUE

The terminal portion of the ileum is used to construct the orthotopic T-pouch ileal neobladder (Figure 39.1). The distal mesenteric division is best made along the

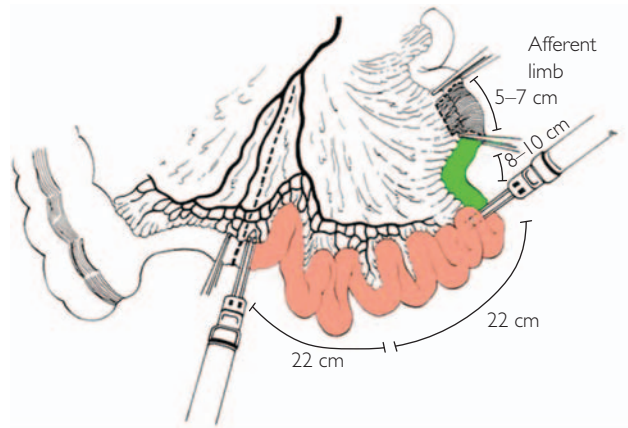


Figure 39.1 Designated segments of terminal ileum for construction of the orthotopic T-pouch ileal neobladder. Note that the distal mesenteric division is made between the ileocolic and terminal branches of the superior mesenteric artery which extends into the avascular plane of the mesentery. In addition, a small window of mesentery and a 5–7 cm segment of most proximal small bowel is discarded to allow mobility of the pouch and small bowel anastomosis.

avascular plane of Treves between the ileocolic artery and terminal branches of the superior mesenteric artery. This division extends deep into the avascular portion of the mesentery which is essential for adequate mobility of the reservoir. The proximal mesenteric division, however, is short and provides a broad vascular blood supply to the reservoir. In addition, a small window of mesentery and a 5–7 cm portion of small bowel most proximal to the overall ileal segment are discarded. This too helps ensure mobility of the pouch and small bowel anastomosis.

The T-pouch reservoir is created from a 44 cm segment of distal ileum placed in an inverted 'V' configuration. Each limb of the 'V' measures 22 cm. A proximal 8–10 cm segment of ileum (afferent limb) is used to form the afferent antireflux T-mechanism. Note, if ureteral length is short or compromised, a longer afferent ileal segment (proximal ileum) may be harvested to bridge the ureteral gap.

The ileum is divided between the proximal afferent ileal segment and the 44 cm ileal segment that will form the reservoir portion of the neobladder. The mesentery between these ileal segments does not need to be incised. There is generally adequate mobility of the afferent ileal segment which will ultimately be advanced into the serous-lined ileal trough formed by the base (cephalad) of the two adjacent 22 cm segments of ileum.

The proximal end of the isolated afferent ileal segment is closed with a running Parker-Kerr suture of

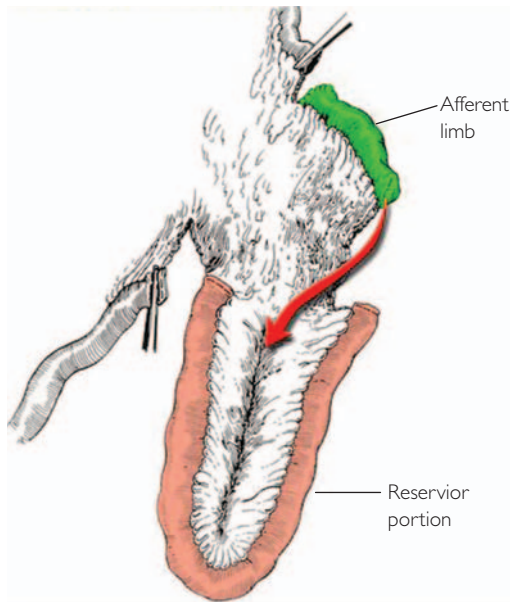


Figure 39.2 The T-pouch is constructed from an isolated 44 cm ileal segment (laid out in an inverted 'V' configuration) which forms the reservoir portion of the pouch, and a proximal 8–10 cm segment of ileum which forms the antireflux limb. The mesentery between the afferent ileal segment and the proximal portion of the 44 cm ileal segment is carefully incised (2 cm) with preservation of the major vascular arcades. Note the serous-lined ileal trough created at the base of the two 22 cm ileal segments where the afferent limb will be advanced (arrow).

3-0 chromic, and a third layer of interrupted 4-0 silk sutures. A standard small bowel anastomosis is performed to re-establish bowel continuity, and the mesenteric trap is closed.

The isolated 44 cm ileal segment is then laid out in an inverted 'V' configuration, the apex of the 'V' lying caudally toward the feet, with a suture marking a point between the two 22 cm adjacent segments of ileum (Figure 39.2). The opened end (base) of the 'V' is directed in a cephalad manner toward the head. Note the serous-lined ileal trough formed at the base of the 44 cm segment.

The antireflux (flap-valve) T-mechanism is then created by anchoring the distal 4 cm of the afferent ileal segment into the serous-lined ileal trough formed by the two adjacent 22 cm ileal segments. First, mesenteric windows of Deaver are opened between the vascular arcades (carefully excising mesenteric fat adjacent to the serosa of the ileum facilitates the development of these mesenteric windows) for 4 cm proximal to the distal most portion of the isolated afferent ileal segment (Figure 39.3). Preserving these arcades (blood vessels) maintains a well vascularized afferent limb and allows permanent fixation of this portion of the limb into the serous-lined ileal

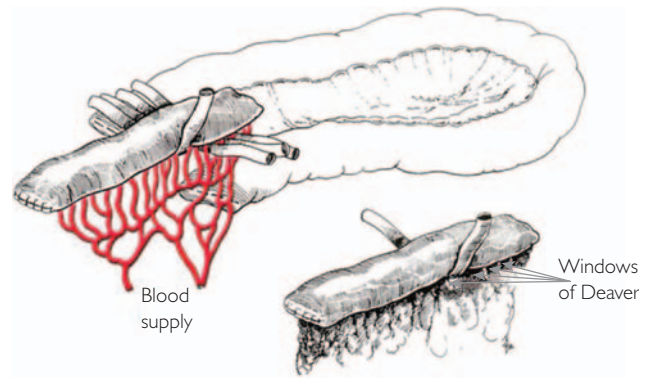


Figure 39.3 Creation of the antireflux mechanism. First, four mesenteric windows of Deaver are opened (adjacent to the serosa of the ileum) at the distal 4 cm of the isolated afferent ileal segment. Placement of small Penrose drains through each mesenteric window helps identify and facilitates passage of suture through each (see inset with arrows). The distal 4 cm of the afferent segment will be anchored into the serous-lined ileal trough formed by the base of the two adjacent 22 cm ileal segments.

trough with complete preservation of the mesentery and blood supply. Placement of small Penrose drains through each mesenteric window helps identify and facilitate passage of suture through each window.

Next, a series of 3-0 silk sutures are used to approximate the serosa of the two adjacent 22 cm ileal segments at the base of the 'V'. These sutures are passed through the previously opened windows of Deaver in the afferent ileal limb. This will anchor the 4 cm segment of afferent limb into the serous-lined ileal trough. Specifically, a silk suture is placed into the seromuscular portion of the bowel (adjacent to the mesentery) at the base (most cephalad portion of the 'V') of one of the 22 cm ileal segments (Figure 39.4A). The suture is then passed through the most proximal window of Deaver opened in the afferent ileal limb (Figure 39.4B) and placed in a corresponding seromuscular site of the bowel (next to mesentery) of the adjacent 22 cm ileal segment (Figure 39.4C). The suture is brought back through the same window of Deaver and tied down (Figure 39.4D). Generally, two to three silk sutures are placed within each window of Deaver to ensure that the back wall of the reservoir is anchored and does not separate. This process is repeated through each individual window of Deaver until the distal 4 cm of the afferent segment is permanently fixed in the serous-lined ileal trough. We have found that placement of small (1/4 inch) Penrose drains through each window of Deaver facilitates passage of the silk suture back and forth through the mesentery without difficulty. The Penrose drains are systematically removed as the afferent limb is fixed within the serous-lined ileal trough.

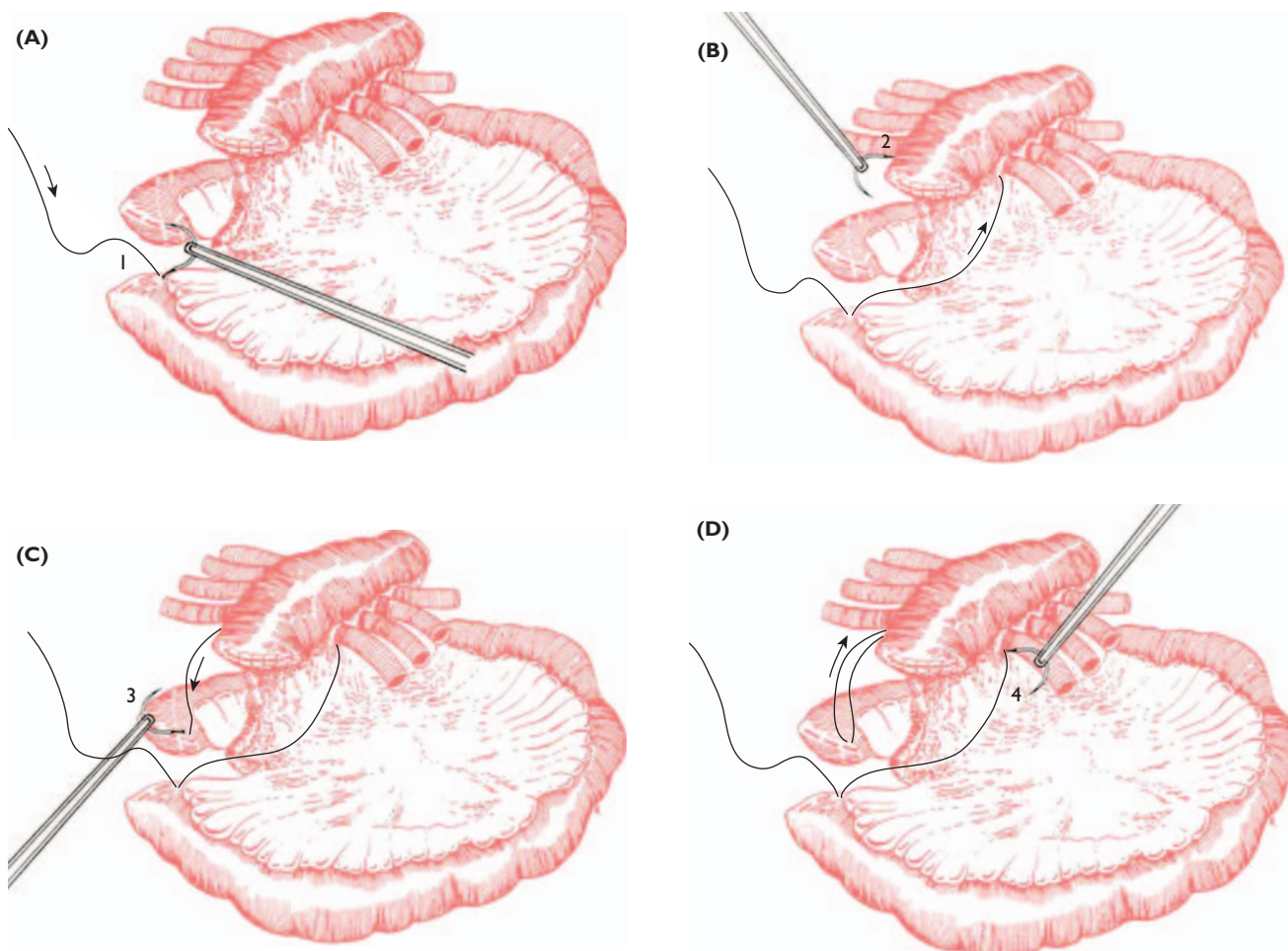


Figure 39.4 A series of interrupted silk sutures are used to approximate the serosa of the base of the two adjacent 22 cm ileal segments. Note these sutures are brought through the windows of Deaver facilitated by the use of the Penrose drains. After passing the silk suture through the window of Deaver, it is placed in a corresponding site on the adjacent 22 cm ileal segment. A silk suture is first placed into the seromuscular portion of the bowel (adjacent to the mesentery) at the base (most cephalad portion of the 'V') of one of the 22 cm ileal segments (A). The suture is then passed through the most proximal window of Deaver opened in the afferent ileal limb (B) and placed in a corresponding seromuscular site of the bowel (next to mesentery) of the adjacent 22 cm ileal segment (C). The suture is brought back through the same window of Deaver and tied down.

In our early experience with the T-pouch, the previously anchored portion of the afferent ileal segment (distal 4 cm) was consistently tapered on the antimesenteric (anterior) border over a 30 Fr catheter (Figure 39.5). Tapering this portion of the afferent ileal segment reduces the bulk and lumen of the afferent limb, and facilitates later coverage of the anchored afferent limb with ileal flaps. In addition, this tapering of the afferent limb increases the tunnel length to lumen diameter ratio, providing a more effective flap-valve mechanism. However, we have found that this may not be necessary and it is now only performed in the situation where the ileal afferent segment has an obviously large diameter.

After the distal 4 cm of the afferent ileal segment has been anchored into the serous-lined tunnel, the remaining portion of the adjacent 22 cm ileal segments are approximated together with a side-to-side 3-0 polyglycolic acid suture. This suture line simply reapproximates the two ileal limbs and is placed adjacent to the mesentery (Figure 39.6). This can be performed in a running or interrupted fashion.

Next, starting at the apex of the 'V', the ileum is opened immediately adjacent to the previously placed serosal suture line using electrocautery. This incision is carried upward toward the ostium of the afferent limb where the afferent limb is anchored (Figure 39.7A). Once this incision reaches the level of the afferent ostium, the incision

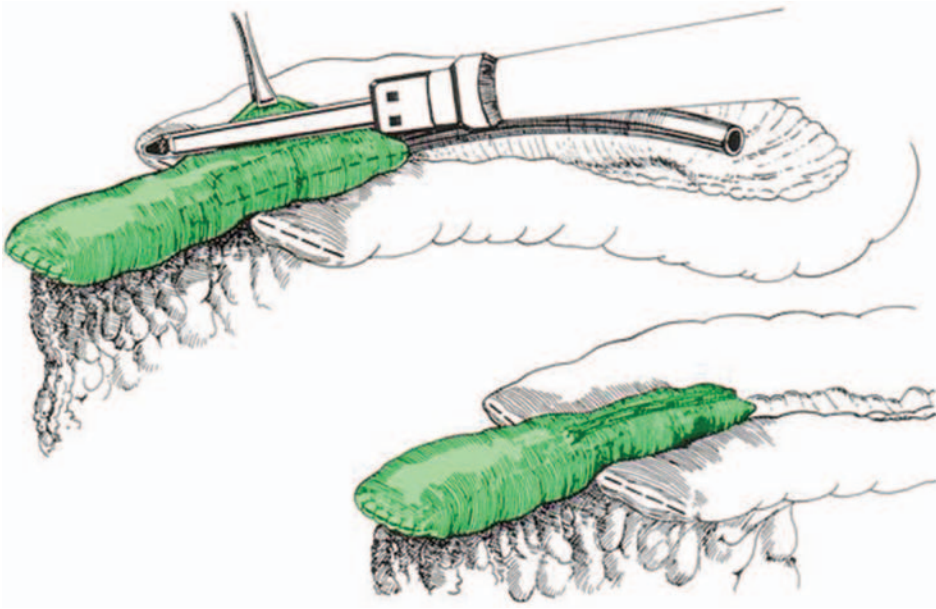


Figure 39.5 The previously anchored distal 4 cm afferent ileal segment can be tapered over a 30 Fr catheter on the anti-mesenteric border. Since the initial description of the T-pouch, we now selectively taper the afferent limb only in those cases where there is clearly a large diameter of ileum.

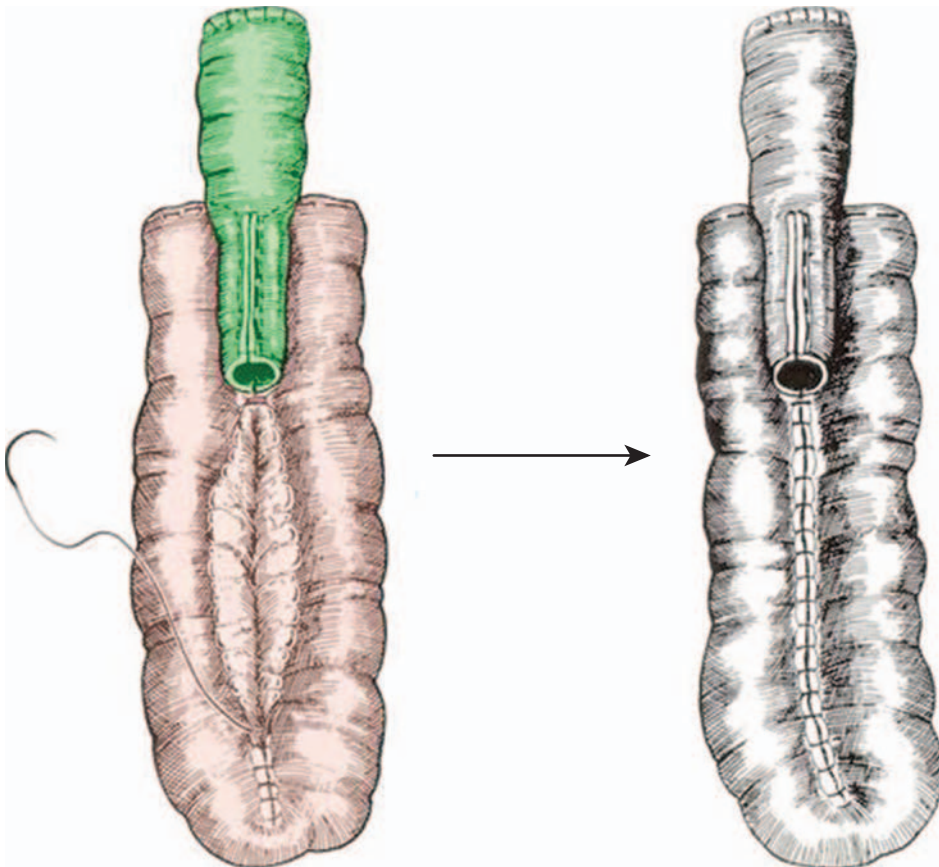


Figure 39.6 The two 22 cm ileal segments are joined by a running 3-0 polyglycolic acid continuous suture. Note that this suture is placed adjacent to the mesentery and runs from the apex up to the ostium of the afferent ileal segment. The serosa of the two 22 cm ileal segments is reapproximated.

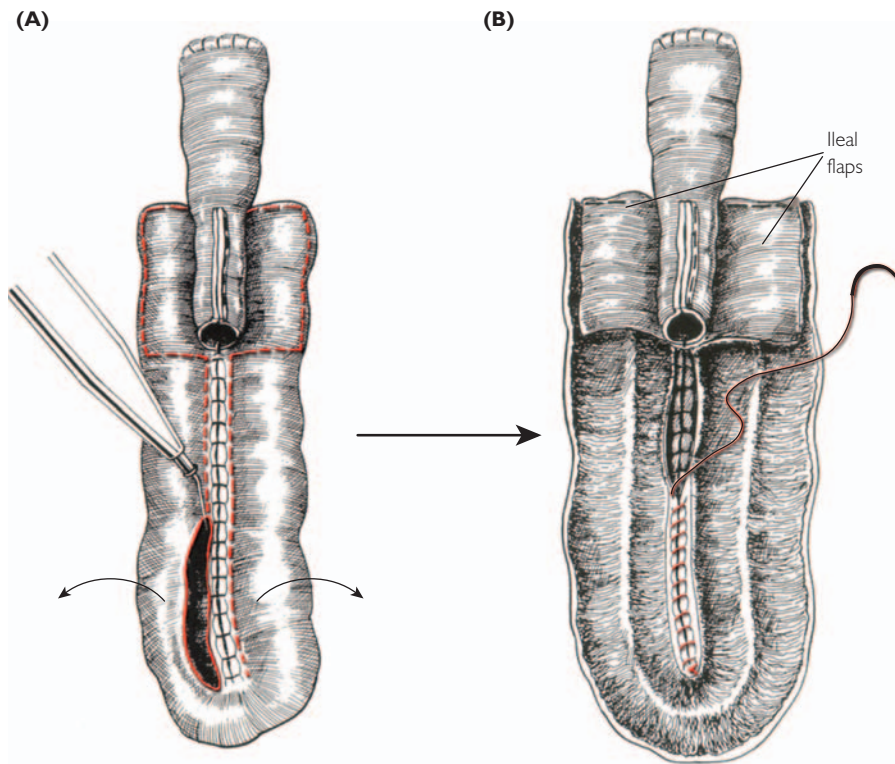


Figure 39.7 (A) The two 22 cm ileal segments are opened immediately adjacent to the serosal suture line beginning at the apex and carried upward to the ostium of the afferent segment. Note that once this incision reaches the ostium it is then directed lateral (to the antimesenteric border) and cephalad to the base. The dashed line depicts the incision line. (B) Completing the incision of the bowel. Note that the incision provides wide flaps of ileum that can easily be brought over to cover the tapered distal afferent ileal segment to form the antireflux mechanism in a flap-valve technique.

is then extended directly lateral to the antimesenteric border of the ileum, and carried upward (cephalad) to the base of the ileal segment. An incision is made in a similar fashion on the contralateral 22 cm ileal segment. Once completed, these incisions provide wide flaps of ileum that will ultimately be brought over and cover the anchored afferent ileal segment to create the antireflux mechanism in a flap-valve technique (Figure 39.7B).

The previously incised ileal mucosa is then oversewn with two layers of a running 3-0 polyglycolic acid suture starting at the apex and continuing upward toward the ostium of the afferent limb (Figure 39.8). Once the ostium of the afferent limb is reached, the running suture is tied. An interrupted mucosa-to-mucosa anastomosis is then performed between the ostium of the afferent ileal limb and the incised intestinal ileal flaps with 3-0 polyglycolic acid sutures (Figure 39.9). The mucosal edges of the ileal flaps are then approximated over the tapered portion of the afferent ileal limb (4 cm) with a running suture in two layers (Figure 39.10). This suture line completes the posterior wall of the reservoir and creates the effective flap-valve T-mechanism: the serous-lined ileal antireflux limb.

The reservoir is then closed by folding the ileum in half, in the opposite direction to which it was opened (Figure 39.11). This effectively creates a low pressure, high capacity urinary reservoir. The anterior wall is closed with a running, two layer 3-0 polyglycolic acid

suture that is watertight (Figure 39.12). This anterior suture line is stopped just prior to the end of the right side to allow insertion of an index finger. This is the most mobile and dependent portion of the reservoir and will later be anastomosed to the urethra.

Once the pouch has been closed, each ureter is spatulated and a standard, bilateral end-to-side ureteroileal anastomosis is performed to the proximal portion of the afferent limb using interrupted 4-0 polyglycolic acid suture. These anastomoses are stented with No. 8 infant feeding tubes which are directed from the ipsilateral renal pelvis (kidney), across the ureteroileal anastomosis through the afferent limb into the reservoir and out of the neourethra. A 24 Fr hematuria catheter is placed per urethra to provide adequate drainage of the reservoir. The ureteral stents are secured to the end of the urethral catheter with a 2-0 nylon suture. This facilitates removal of the stents at approximately 3 weeks along with the urethral catheter. A tension free mucosa-to-mucosa urethroileal anastomosis is performed.

DISCUSSION

Critical components to the success of lower urinary tract reconstruction include the ability to create a large capacity, low pressure reservoir with an adequate continence mechanism to store urine. Kock's landmark report in

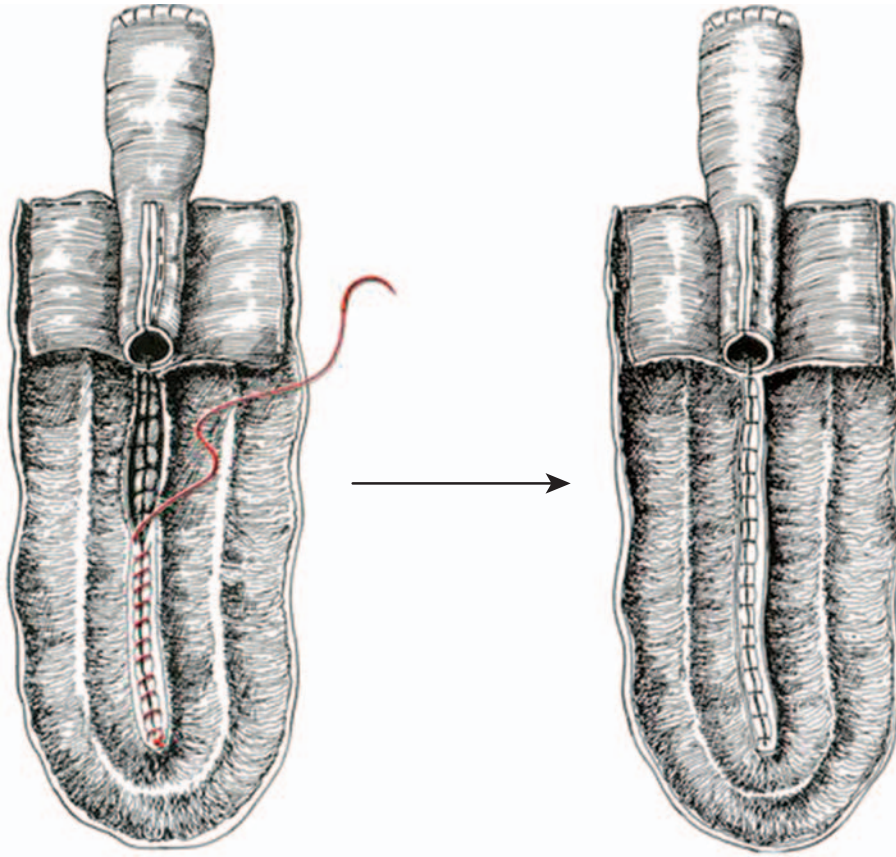


Figure 39.8 The incised ileal mucosa is oversewn in two layers beginning at the apex and continuing toward (cephalad) the ostium of the afferent ileal segment.

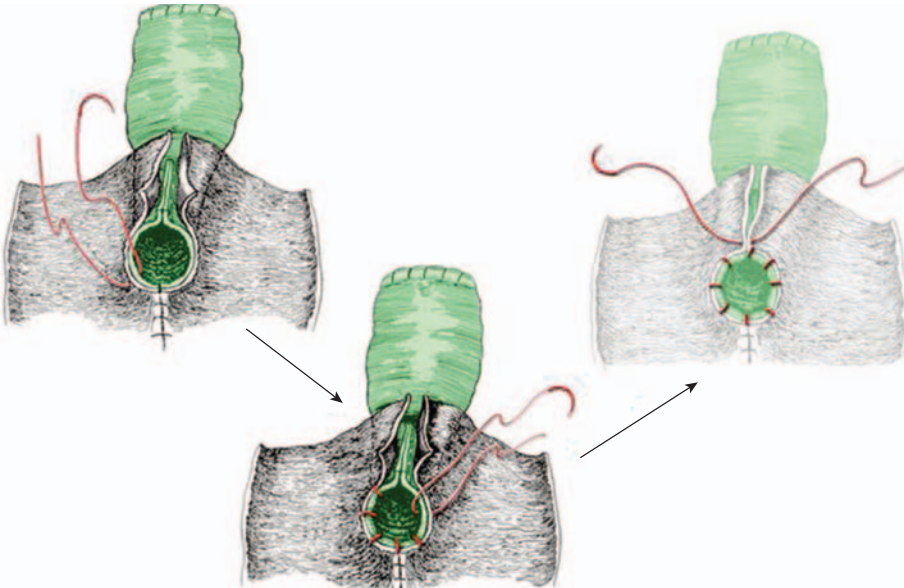


Figure 39.9 A mucosa-to-mucosa, ileal-to-ileal anastomosis is performed between the ostium of the afferent segment and the edges of the ileal flaps. Note that this is performed with interrupted 3-0 polyglycolic acid suture with completion of the ileal-to-ileal anastomosis.

1982⁶ stimulated enthusiasm toward a continent cutaneous form of urinary diversion, and inspired the development of a wide variety of continent cutaneous urinary reservoirs. The continent cutaneous urinary reservoir naturally evolved to an orthotopic form of reconstruction, eliminating the cutaneous urostomy,

stoma, and the need for catheterization in most patients. Orthotopic urinary diversion subsequently became the procedure of choice in both male and female patients requiring cystectomy during the mid- and late 1980s.¹

The development of orthotopic reconstruction was a significant improvement in the evolution of urinary

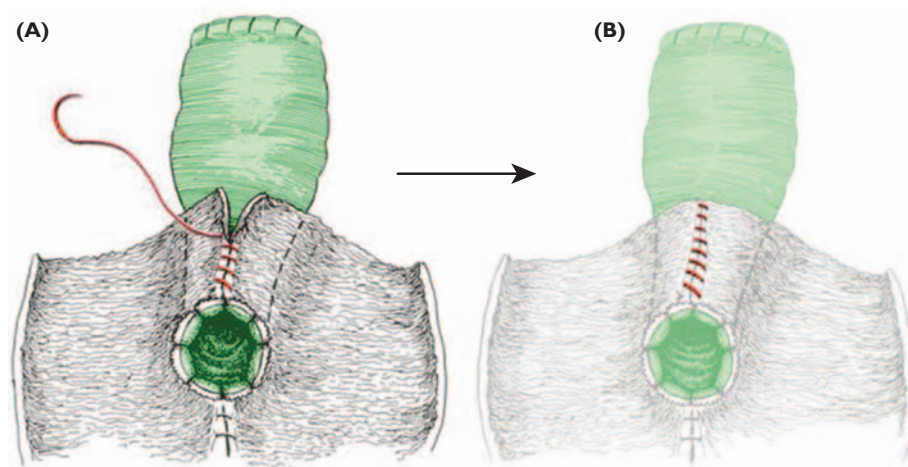


Figure 39.10 (A) The mucosal edges of the ileal flaps are brought over the tapered distal portion of the afferent ileal segment. (B) Completion of the posterior suture line covering the afferent segment with the ileal flaps. Note that this will exclude the staple line from the reservoir.

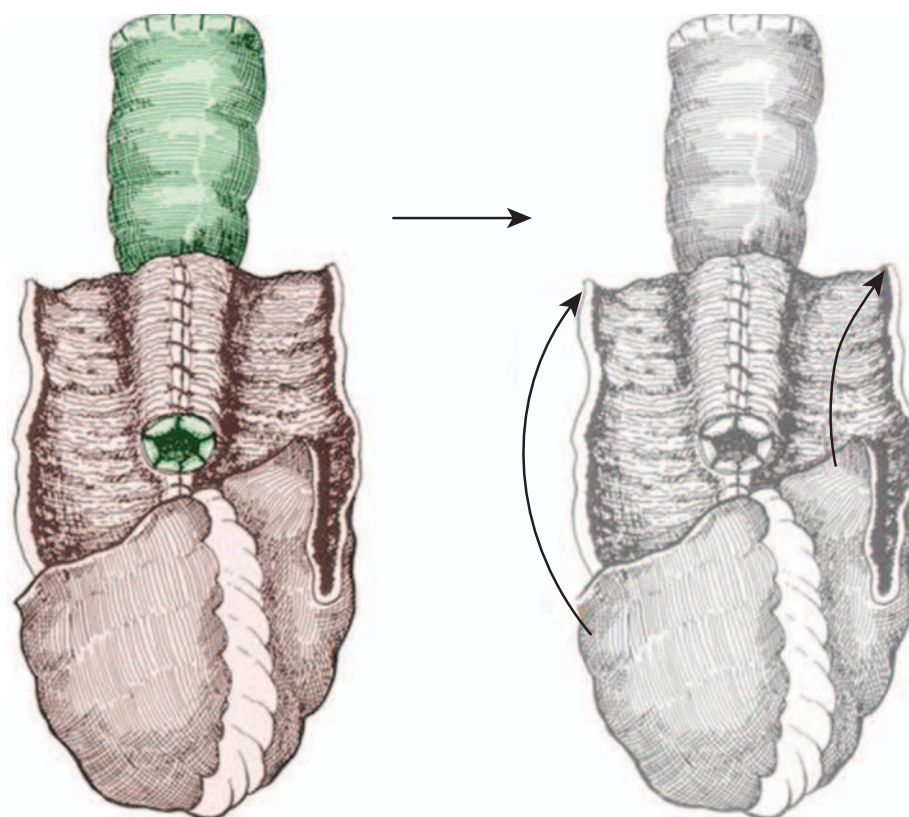


Figure 39.11 The T-pouch is folded (see arrows) and closed in the opposite direction to which it was opened. This manner of folding will create a low pressure, large capacity spherical reservoir.

diversion. The importance of preventing the reflux of urinary constituents following orthotopic reconstruction is a controversial subject and remains a topic of significant debate. We have been, and continue to be, proponents of reflux prevention in all patients undergoing lower urinary tract reconstruction. It is emphasized that the complications or risks associated with incorporating an antireflux mechanism (i.e. obstruction) should not outweigh the theoretical advantage of reflux prevention. To meet this end, we have been diligent to

critically evaluate our antireflux techniques and continually improve upon existing ideas and methods. This evaluation process has subsequently stimulated a change from the intussuscepted nipple of the Kock pouch, to the development of the flap-valve T-mechanism, incorporated as an antireflux limb in the orthotopic T-pouch ileal neobladder.^{16,17} This technique provides an effective antireflux mechanism without the complications associated with the intussuscepted nipple. Furthermore, the T-mechanism has been applied as

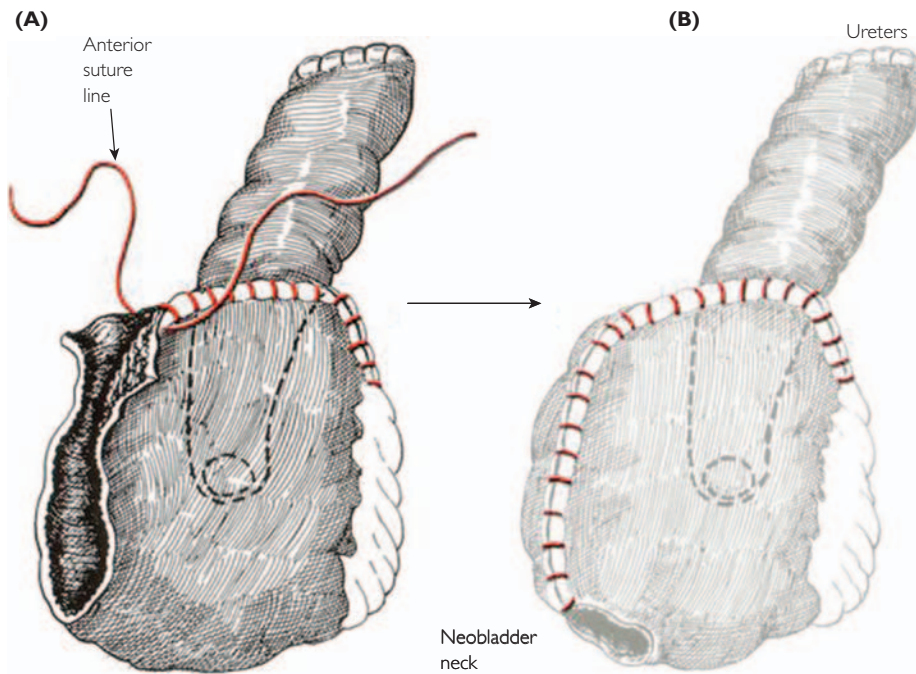


Figure 39.12 (A) The anterior suture line is completed with two layers of a continuous 3-0 polyglycolic acid suture. Note that the anterior suture line is stopped just short of the right side to allow insertion of an index finger creating what will be the neourethra. (B) Completion of the T-pouch. Note the most mobile and dependent portion of the reservoir will be anastomosed to the urethra following the ureteroileal anastomosis to the proximal portion of the afferent limb.

a catheterizable continent mechanism in cutaneous reservoirs as discussed elsewhere.¹⁸

With appropriate long-term follow-up, problems with urinary reflux became evident in patients undergoing various forms of urinary diversion including ureterosigmoidostomy,¹⁹ and ileal conduit urinary diversion.^{20,21} Richie and Skinner demonstrated in canine experiments that infected reflux of urine could lead to renal impairment and suggested that antireflux techniques should be considered.^{22,23} The application of an antireflux mechanism was supported experimentally in colon conduits; however, with longer follow-up renal deterioration also became problematic in these patients,^{24,25} thought to be related to high pressures, obstruction, and chronically infected urine.

Many antireflux techniques exist today.²⁶ The inclusion of an antireflux mechanism in the chronically infected, continent cutaneous reservoir (requiring intermittent catheterization) is important and not a source of considerable debate. With increasing popularity and further application of the low pressure orthotopic reservoir, the issue of reflux prevention has regained attention. Studer et al advocate a long (20 cm), dynamic, isoperistaltic ileal segment as the afferent limb of an orthotopic neobladder reservoir.²⁷ Proponents of the isoperistaltic afferent ileal limb argue that radiographic evidence of reflux in a sterile, low pressure reservoir may not have the same importance and clinical consequences. Furthermore, the

complications of late stenosis from the various antireflux techniques could potentially outweigh their theoretical advantage of protecting the upper urinary tract. Others, however, argue that antireflux procedures are not only theoretically inherent in humans, but also are critical to preserve or maintain renal function and are important in all forms of lower urinary tract reconstruction, even orthotopic diversion. Reasons include the fact that patients, even with an orthotopic neobladder, may have colonized bacteriuria. The unexpected patient requiring intermittent catheterization to completely empty their neobladder (which is unpredictable) will also expectedly have colonized bacteriuria with the risk of upper tract deterioration. Experimental data in canines undergoing a low pressure enterocystoplasty with refluxing ureteric implantation support this notion, as these dogs were found to have bacteriuria in the upper urinary tract and pyelonephritis.²⁸

Reflux prevention following orthotopic diversion may become more important as the comprehensive therapy (medical and surgical) for pelvic malignancies improves and patients' life expectancy increases following exenteration and urinary diversion. This may then place patients at further risk for renal deterioration in the future. Subsequently, several novel antireflux mechanisms have been developed to improve on existing techniques and eliminate or reduce the complications associated with previous antireflux mechanisms,

particularly obstruction.^{15–17} Longer follow-up will be required to accurately evaluate the isoperistaltic afferent limb, as well as these more recent antireflux techniques, to determine if reflux prevention in patients undergoing orthotopic diversion is truly necessary.

From 1982 to 1997, we incorporated the intussuscepted nipple valve as an antireflux mechanism in all forms of continent urinary diversion at USC, and as an efferent continence mechanism in patients undergoing a cutaneous Kock ileal reservoir.^{4,7,8} The basic surgical premise and structural characteristics of the Kock ileal reservoir are sound: low pressure, large capacity reservoir, and employing an antirefluxing and continent nipple valve. The Achilles heel of the Kock ileal reservoir, however, remains the intussuscepted nipple valve. Despite several surgical modifications to improve upon the construction of the intussuscepted nipple valve, there remain complications and a reoperation rate.^{12,13,29,30} It was clearly necessary to improve upon the intussuscepted nipple valve.

The so-called 'T-mechanism' is a flap-valve technique which can be applied as an antireflux and continence mechanism in lower urinary tract reconstruction.^{16–18} In general, all flap-valve techniques rely on the dynamic principle that the channeled segment (appendix, ureter, intestine) is fixed and tunneled along the inner wall of the reservoir. As reservoir filling occurs, the channeled segment is compressed against the wall of the pouch and continence or reflux prevention is achieved. This technique is based on similar principles to those for reimplantation of the ureter into the bladder. Keys to success of the flap-valve technique include an appropriate tunnel length to lumen diameter ratio. Furthermore, the backwall of the reservoir must be sufficiently capable to allow compression of the tunneled channel as the pouch fills.

The unique aspect of the T-mechanism (antireflux and continence) is the ability to create a reliable and effective flap-valve system. Maintenance of the vascular arcades (opening the windows of Deaver) provides complete preservation of the mesentery and blood supply to the entire limb, thus eliminating problems with ischemia or stenosis of the bowel segment. Permanent fixation of the limb into the serous-lined ileal trough should also eliminate issues associated with prolapse or extussusception of the limb. Importantly, no exposed metallic staples exist within the reservoir which should reduce the incidence of stone formation typically associated with exposure of metallic foreign bodies to urine. Furthermore, if necessary the proximal portion of the afferent limb can be easily lengthened when there are shortened or compromised ureters. A longer

proximal afferent segment may be harvested to bridge any ureteral defect to maintain a tension-free ureteroileal anastomosis.

Several technical points regarding the specifics of the construction of the flap-valve T-mechanism (antireflux, continence) deserve mentioning. An effective afferent antireflux valve can be created from 4 cm of ileum anchored within the serous-lined ileal trough. Permanently anchoring this portion of ileum in the serous-lined ileal trough is critical to fix the limb and prevent any valve slippage or prolapse. In addition, the silk sutures used to anchor the valve (passed through the windows of Deaver) should be placed adjacent to the mesentery, and should incorporate a generous portion of the seromuscular ileum to prevent separation of the serous-lined ileal trough. This trough forms the so-called 'backboard' (posterior wall to the reservoir) of the flap-valve technique which is critical to antireflux prevention as the reservoir fills. Placement of two to three sutures within each window of Deaver should prevent separation of this trough.

The antimesenteric tapering of the valve was initially described and performed on all patients with this technique. Tapering the afferent limb over a 30 Fr catheter has been effective in preventing reflux of urinary constituents and protecting the upper tracts in patients undergoing an orthotopic T-pouch ileal neobladder.¹⁷ This effectively increases the tunnel length to lumen diameter ratio and has provided an excellent efferent continence mechanism. However, several patients (2%) with longer follow-up have developed some narrowing of the ostium that may be attributed to either some postoperative radiation to the reservoir or possibly to the antimesenteric tapering.¹⁷ We subsequently now tapered the T-limb only in patients with a large ileal diameter and have found that it does not compromise the antireflux mechanism and may eliminate any issues of ostial stenosis.

The flap-valve T-mechanism in the T-pouch provides an effective and reliable antireflux mechanism. The long-term results of the T-pouch are yet to be determined; however, the initial and intermediate results have been promising.^{16,17} Furthermore, we believe that this technique can be easily learned with a little experience. The T-mechanism is a versatile flap-valve technique that can also be applied as a continent mechanism in a cutaneous reservoir (double-T-pouch). We believe that reconstructive surgeons interested in lower urinary tract reconstruction should understand this concept and technique to broaden their surgical armamentarium.

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40 Right colon neobladder

Ludger Franzaring and Joachim W Thüroff

Orthotopic bladder substitution has become standard for urinary diversion after radical cystectomy. The goal of orthotopic bladder substitution is to create a reservoir of adequate capacity at low pressures, to protect the upper urinary tract, and to achieve urinary continence. However, there is a great variety of bowel segments and configurations used for bladder substitution, of techniques of ureter implantation, and of mechanisms of reflux prevention.

Regarding bowel segments and configurations, there exist a number of different ileal neobladders and colonic bladder substitutes.^{1–8} To date, no single technique has proven to be of significant advantage over another.

Colon segments are used either alone or in combination with small bowel segments. Due to the larger diameter of colon segments, the same capacity of a reconfigured bladder substitute can be obtained with less than half the length of large bowel as compared with small bowel. This is relevant since only resection of ileum may result in malabsorption syndromes such as those of biliary acids, folic acid, and vitamin B12, and other fat soluble vitamins.^{9,10} Racioppi et al demonstrated, in a series of 50 patients with a mean follow-up of 59.8 months, that there was a tendency towards lower vitamin B12 levels in patients in whom ileum was used, but after ileocolonic reservoirs were used the vitamin B12 level remained significantly higher than after ileal neobladders.¹¹ However, with a follow-up of more than 5 years in the Mainz series, one-third of patients with an ileocolonic reservoir required also vitamin B12 supplementation.¹²

Concerning the acid-base and electrolyte balance Racioppi et al found no difference between patients with ileal and ileocolonic neobladders.¹³

Other advantages of using large bowel are that ureters can be implanted with different antireflux techniques such as submucosal tunnel for ureters of normal caliber or serosa-lined tunnel for dilated ureters.^{6,14}

After detubularization of the segments, pressures of a right colonic reservoir do not exceed 40 cmH₂O, which is of importance regarding continence and reflux.^{15,16}

INDICATIONS

If preservation of the urethra is indicated in cystoprostatectomy in males or cystectomy in females,

orthotopic bladder substitution is an option. As in all other orthotopic bladder substitutes, the right colon or ileocecal bladder substitution is indicated in cases of bladder cancer not involving the prostatic urethra and the urethral stump, which is determined by preoperative biopsies from the prostatic urethra at the time of transurethral resection of bladder tumors and by frozen sections from the urethral stump taken during radical cystectomy. In case of benign indications (interstitial cystitis, low compliance bladders, detrusor hyperreflexia), bladder substitution using ileocecal or colon segments can be performed to the bladder neck or to the trigone depending on the necessity of ureteral reimplantation as determined by the presence of vesicoureteral reflux or obstruction.

In general, orthotopic bladder substitution is not recommended to patients with more than 50% reduction of kidney function, because metabolic acidosis will result from enterorenal circulation with electrolyte and acid reabsorption from the intestinal bladder substitute but insufficient renal excretion. Since in the elderly renal reserve and urinary sphincteric control are decreasing, indications for orthotopic substitution are limited to patients below the age of 70–75 years. In case of a single functioning kidney, a higher risk of postoperative decrease in kidney function must be considered for orthotopic as compared with cutaneous diversion, which is, however, highest for rectal reservoirs.¹⁷ Close follow-up of renal drainage and function is mandatory and incontinent cutaneous conduit diversion may be a preferable alternative.

In females a 20–40% risk of postvoid residual urine or complete retention must be considered. In these cases, intermittent catheterization will be necessary, which, particularly in handicapped or obese patients, is more difficult via urethra than with a continent stoma.

GENERAL SURGICAL ASPECTS

Optical loupes (2.5–3.5 × magnification) and a headlight are essential for precise preparation of the urethral stump and neurovascular bundles in case of nerve-sparing cystectomy. Frozen sections of the urethral stump are required to rule out urethral tumor

involvement. Eight anastomotic 4-0 monofilament poly- α -dioxanone sutures, double armed with 5/8 needles are placed through the urethral stump. In case of urethral tumor involvement or obstruction after prior surgery or radiation a greater length of ureter has to be resected and subtotal or total ureteral replacement becomes necessary. This must be considered for resection of bowel segments for pouch formation, since one additional bowel segment has to serve as ureteral substitute.¹⁸

After isolation of the ileocecal segments ileocolostomy is performed as a spatulated end-to-end anastomosis. Intraoperative irrigation of isolated segments with 1–2 liters of saline serves for further cleansing of the bowel. Ureters are stented with 6–8 Fr polyurethane catheters and the orthotopic pouch is drained by a 10 Fr transmural pigtail catheter and a 20–22 Fr transurethral Foley catheter.

In 1986, two different techniques of ileocecal orthotopic bladder substitution (Mainz pouch and Le Bag) were introduced.^{6,19} Differences between these two techniques include the length of isolated bowel segments, and the ureterointestinal and the urethrointestinal anastomoses. In the Le Bag technique the ureters are implanted by either refluxing or non-refluxing techniques, with no significant difference of ureteral obstruction.⁷ In the original Mainz pouch procedure the ureters are implanted by a non-refluxing submucosal tunnel technique. An end-to-side urethrointestinal anastomosis is performed at the deepest point of cecum in the Mainz pouch procedure as compared with the end-to-end anastomosis of the urethra with tapered tubular proximal ileum in the Le Bag procedure.

ORTHOTOPIC MAINZ POUCH

The orthotopic Mainz pouch has been used since the 1980s and has stood the test of time in respect of providing adequate reservoir capacity at low pressures and protecting upper tracts. However, the original technique has been criticized as being tedious and time consuming, hence below the original technique and the modified technique of 2003 are presented.^{18,20}

Original technique

The left ureter is passed cranially to the inferior mesenteric artery into the right retroperitoneum.

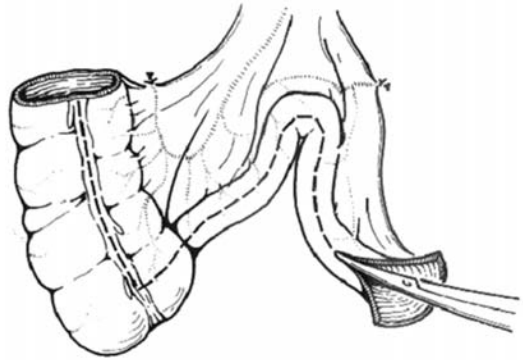


Figure 40.1 For pouch formation, 10–15 cm of right colon and two ileal loops of the same length are isolated and split open lengthwise at their antimesenteric borders. From reference 6, with permission.

For pouch formation, 10–15 cm of cecum and ascending colon and two segments of terminal ileum (20–30 cm) of equal length are used (Figure 40.1). After isolation of the ileocecal segments on the pedicle of the ileocolic artery, bowel continuity is re-established with an end-to-end anastomosis after antimesenteric spatulation of ileum to adjust for differences in bowel diameter using single-row seromuscular 4-0 glyconate monofilament, running sutures. After irrigation of the isolated ileocecal segments with 1–2 liters of isotonic saline an appendectomy is performed and the bowel is split lengthwise antimesenterically. For pouch formation, the ileum segments are anastomosed in a 'U' shape side-to-side to each other and again to the cecum and ascending colon. Anastomosis is performed using all-layer 4-0 glyconate monofilament absorbable running sutures. When the posterior wall of the pouch is completed, both ureters are implanted via parallel submucosal tunnels into the colon segment (Figure 40.2). Ureters are stented with 6–8 Fr polyurethane stents, which are removed on the 10th postoperative day. At the deepest point of the pouch the urethrointestinal anastomosis is performed after excision of 0.5 cm seromuscularis and eversion of the mucosa (Figure 40.3). A 20–22 Fr transurethral Foley catheter is left in the substitute bladder for 10–12 days and is removed when a pouchogram demonstrates absence of extravasation. If the ileocolic artery is too short to slide the pouch into the true pelvis, a 180° counter-clockwise rotation of the pouch facilitates tension-free urethrointestinal anastomosis. For bladder substitution to the bladder neck or trigone the ileocecal pouch is anastomosed to the bladder neck or trigone with all-layer running sutures (Figure 40.4).

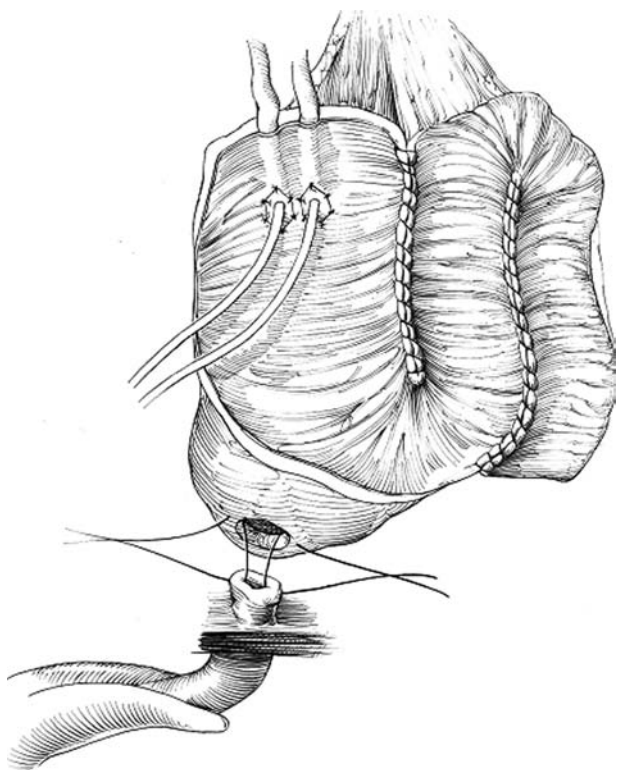


Figure 40.2 The posterior wall of the pouch is established by side-to-side anastomosis of the margins of ileum and colon. Ureters are implanted by submucosal tunnels and urethrointestinal anastomosis is established at the deepest point of the cecum. From reference 6, with permission.

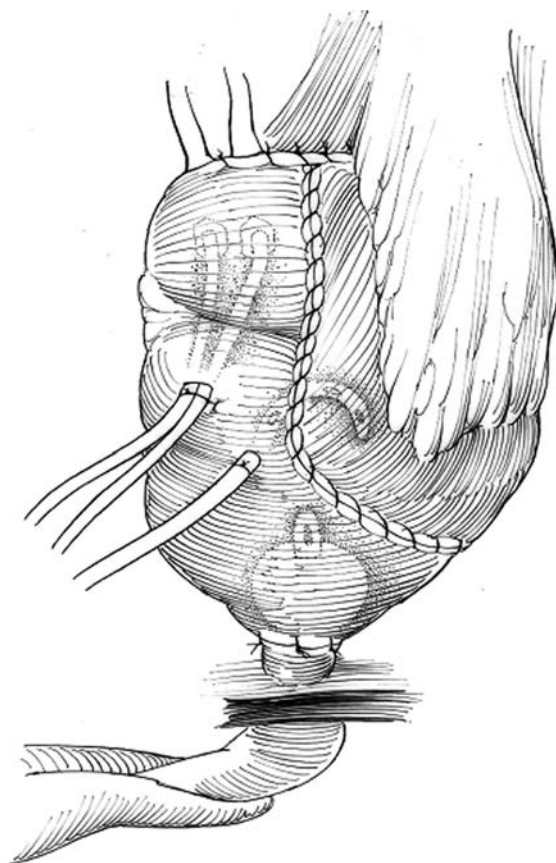


Figure 40.3 After transmurial externalization of stents (6–8 Fr), insertion of a 10 Fr pouchostomy pigtail catheter, and transurethral placement of a 20–22 Fr Foley catheter, the anterior pouch wall is closed. From reference 6, with permission.

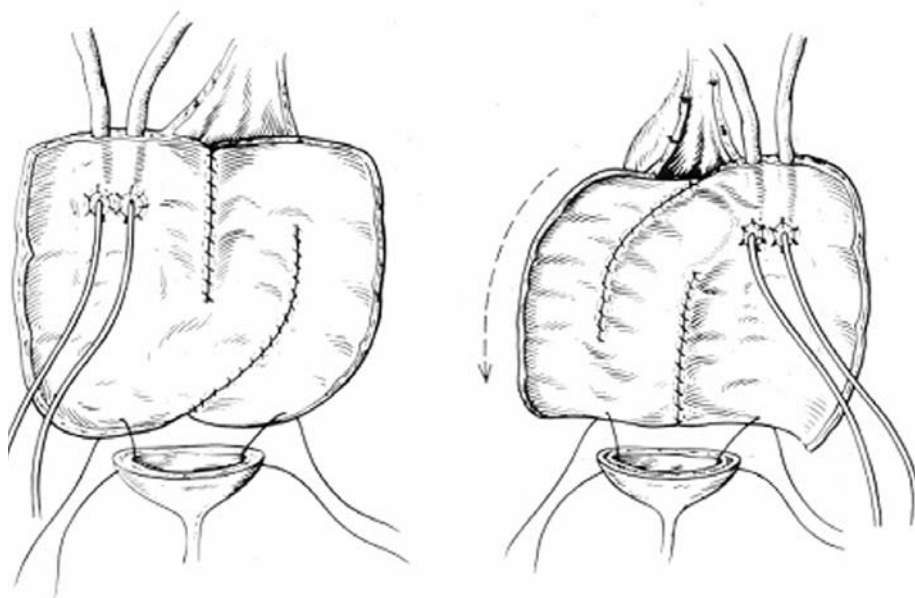


Figure 40.4 For subtotal bladder substitution in benign diseases, the ileocecal pouch is sutured to the bladder remnant. If the ileocolic vessels are too short for sliding the bowel segment down into the true pelvis, 180° rotation facilitates a tension-free anastomosis. From reference 6, with permission.

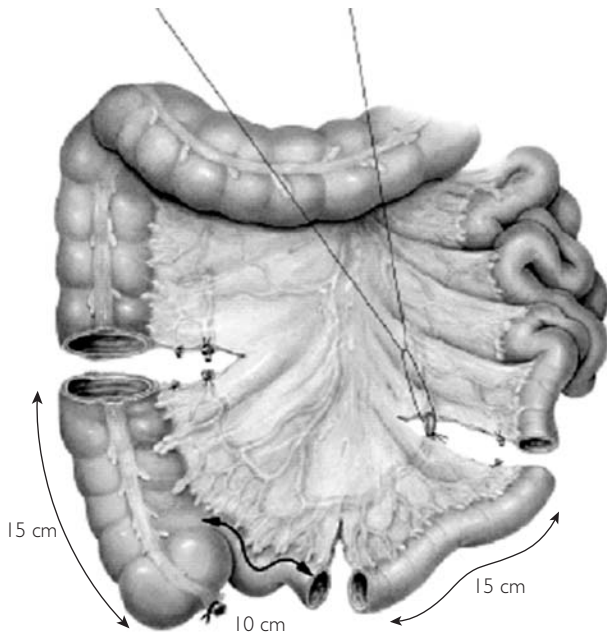


Figure 40.5 The ileocecal segments are isolated and the terminal ileal segment is divided into two parts (stapled version). From reference 18, with permission.

Modified technique

The modified technique employs the ileocecal valve as an antireflux mechanism with standard Nesbit and Wallace ureter implantation into the preavalvular ileum, which can serve as a partial or even complete ureteral substitute if ureters have to be resected short because of tumor involvement or radiation damage.

Ureteral implantation into the preavalvular ileum with the ileocecal valve serving as an antireflux mechanism has been described for non-refluxing ileocecal conduit²¹ and for continent cutaneous urinary diversion.²²

To speed up the surgical procedure, gastrointestinal anastomosis (GIA) 75 staplers with absorbable staples may be used for pouch formation. Whether suturing or stapling is applied for pouch formation depends on the diameter of the bowel segments and the surgeon's preference. However, the length of the segments to be isolated differs depending on the chosen technique and shape of the reservoir.

Stapled version

For a stapled pouch, 25 cm of terminal ileum and 15 cm of cecum are isolated. After irrigation the proximal 15 cm of ileum are separated from the preavalvular segment (10 cm), which is used for ureteral implantation later (Figure 40.5). Bowel continuity is restored by

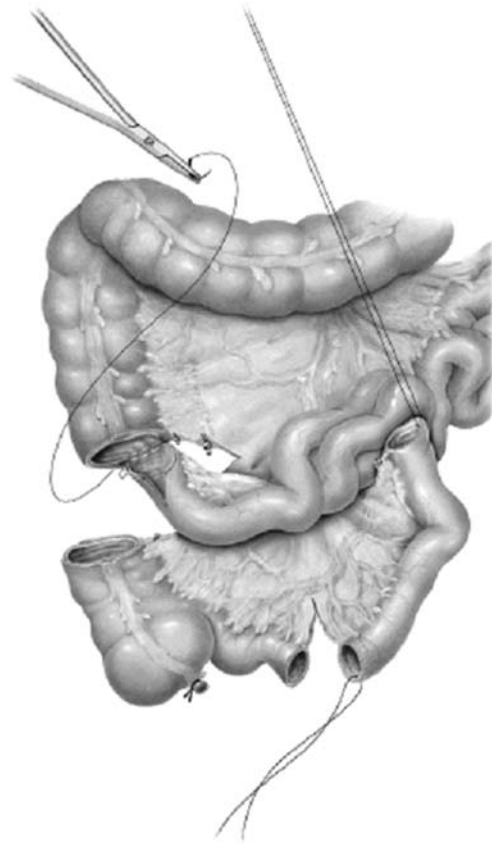


Figure 40.6 Ileoascendostomy is performed by seromuscular 4-0 glyconate monofilic absorbable running sutures. From reference 18, with permission.

end-to-end ileocolostomy using 4-0 polyglyconate monofilament absorbable running seromuscular sutures (Figure 40.6). The ascending colon has to be mobilized up to the right colonic flexure to achieve a tension-free ileocolic anastomosis. After approximation of ileum and cecum, the Poly-GIA 75 stapler is inserted into both bowel segments and in a one-step procedure both segments are cut open and the margins are stapled with two staggered rows on either side of each other (Figure 40.7). When using three to four staplers, the initial pouch capacity ranges between 250 and 300 ml (Figures 40.5 to 40.8).

Sutured version

In case of suturing the pouch, 10 cm of cecum and 30 cm of ileum are isolated. After dividing the ileum into two segments (10 cm preavalvular and 20 cm proximal ileum), the proximal two segments and the cecum are opened antimesenterically and sutured to each other and to the cecum with 4-0 all-layer running sutures (Figure 40.9).

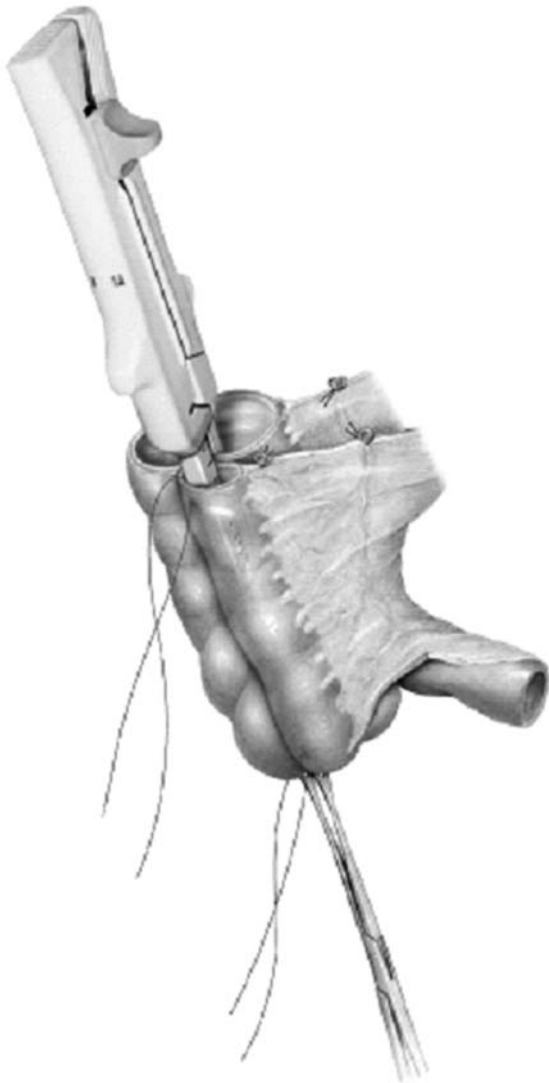


Figure 40.7 Stapled version. For stapling the pouch with reabsorbable staples, 15 cm of right colon and ileum each are collocated and the Poly GIA 75 stapler is inserted. Both bowel segments are cut open and the margins are stapled to each other with two staggered rows of staples on each side in a one step-procedure. From reference 18, with permission.

When the posterior wall of the pouch is sutured, the reservoir is rotated 180° counter-clockwise (Figure 40.10), so that the ileocecal valve and the prevulvar ileum lie cranially. Ureters are implanted into the intact prevulvar segment so that the ileum segment and the ileocecal valve serves as antireflux mechanism (Figure 40.11).

If ureters have to be resected short, the prevulvar segment can serve as a ureteral substitute. Hence, the length of this segment has to be chosen according to the length of the ureteral defect which has to be bridged (Figures 40.9 to 40.12).

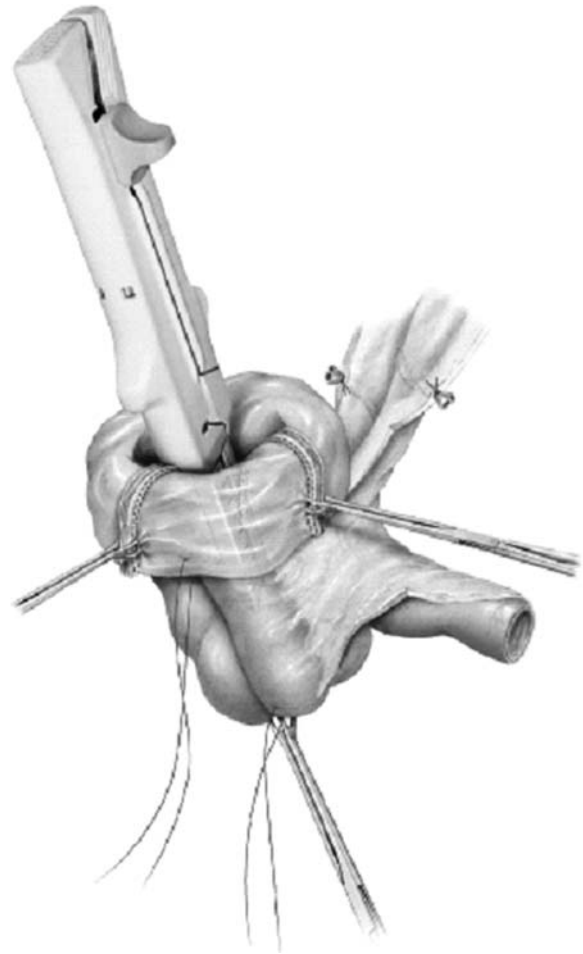


Figure 40.8 After eversion of the bowel the second stapler is applied. When using three to four staplers the initial pouch capacity ranges between 250 and 300 ml. From reference 18, with permission.

LE BAG

After mobilization of the ileocecal segments (colon 20 cm, ileum 20 cm) on their pedicle of the ileocolic vessels, the segments are split open lengthwise at their antimesenteric borders leaving the proximal 3 cm of resected ileum intact (Figure 40.13). The pouch is created by side-to-side anastomosis of ileum and colon. The ileocecal pouch is rotated 180° counter-clockwise into the true pelvis for end-to-end urethrintestinal anastomosis with the intact proximal ileum using six anastomotic sutures. Ureters are implanted once the reservoir is situated in the pelvis to avoid any risk of cutting the ureters too short. In the original technique, ureters are implanted in a submucosal tunnel technique. For subtotal bladder substitution in benign diseases, the ileocecal pouch is anastomosed to the bladder remnant with all-layer running sutures.¹⁹

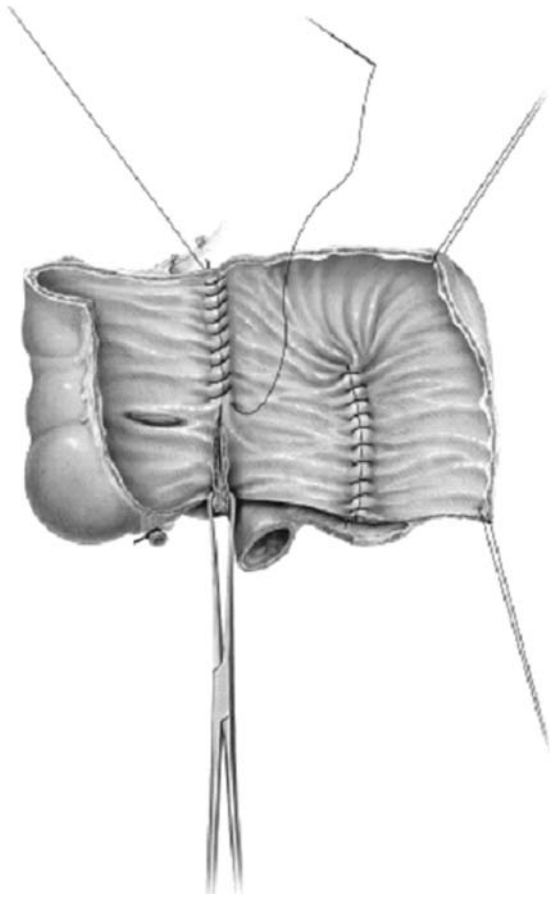


Figure 40.9 Sutured version. After splitting the colon and the proximal 20 cm of ileum, these segments are side-to-side anastomosed by running all-layer 4-0 glyconate monofilic absorbable sutures. From reference 18, with permission.

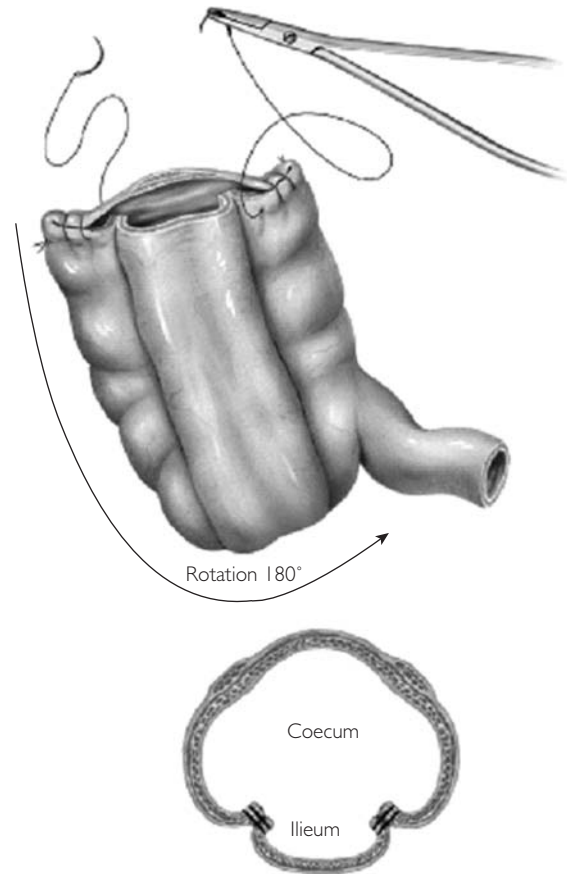


Figure 40.10 The pouch is rotated 180° counter-clockwise, so that prevolvular ileum will lie cranially. From reference 18, with permission.

A modification of the Le Bag procedure was presented in 2004 by Baniel and Tal, who detubularized the cecum, the ileocecal valve, and the distal ileum, and left the proximal 3–5 cm of ileum intact for ureteral implantation into a chimney (Figure 40.13).²³

URETERAL IMPLANTATION INTO COLONIC RESERVOIRS

Concepts of ureterointestinal implantation are still debated and a variety of different techniques have been presented. The ideal ureteral implantation technique should suit ureters of different lengths and calibers, protect the upper urinary tract, have a low risk of anastomotic obstruction and prevent reflux.

The rationale of preventing reflux derives from ureteral implantation into the bladder reservoir and into the intestinal tract in continuity, such as ureterosigmoidostomy and recto-sigmoid pouch.^{24,25} In low pressure

orthotopic urinary diversion it remains under investigation whether a refluxing or a non-refluxing ureteral implantation is preferable. Nevertheless, enteroureteral obstruction has a higher risk of damaging kidney function than enterorenal reflux.²⁶

For ureteral implantation into an orthotopic colonic reservoir, the concepts of reflux prevention or refluxing ureteral anastomosis are executed with different surgical techniques. For reflux prevention, the ureters can be implanted through a submucosal or a serosal-lined tunnel into the large bowel applying the flap-valve principle.^{14,27} Another technique is the split-cuff technique, in which the ureter itself is fashioned into a nipple as an antireflux valve.²⁸

Pantuck et al experienced higher anastomotic obstruction rates with antirefluxing ureteral implantation with the technique of Leadbetter, Le Duc, and Goodwin than with the end-to-side refluxing technique. In their study, 13% of ureters with antirefluxing ureterointestinal anastomosis and only 1.7% of ureters

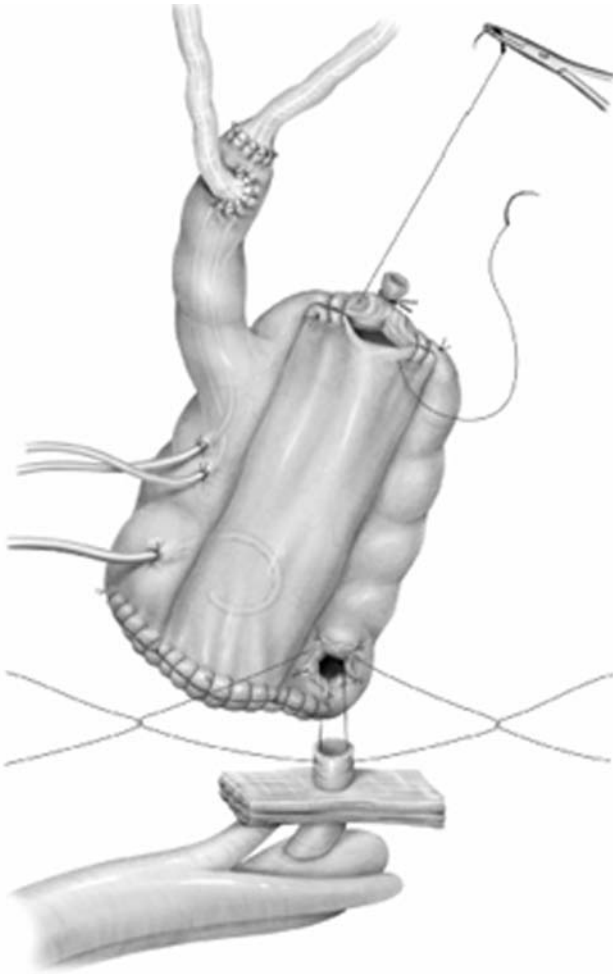


Figure 40.11 Ureters are directly implanted into the preterminal segment by Nesbit and Wallace techniques. The urethrointestinal anastomosis is performed at deepest point of the pouch using eight 4-0 monofilament absorbable sutures double armed with 5/8 needles. From reference 18, with permission.

with direct refluxing implantation developed an obstruction.²⁹ This is a lower stricture rate than with direct ureter implantation into an ileal conduit. Madersbacher et al reported a 10% risk of stenosis of the ureterointestinal anastomosis in ileal conduits with a follow-up of more than 5 years.³⁰ In our original series of Mainz pouch orthotopic ileocecal bladder substitution with tunneled, antirefluxing ureteral implantation, the ureteral obstruction rate was 7%, which remained the same in the modified technique with direct ureteral implantation.^{20,31}

In direct refluxing ureteral anastomosis into an isoperistaltic 'chimney' of intact ileum, peristaltic contractions of bowel may support urinary drainage from the ureters into the reservoir. This is claimed to provide a mechanism of reflux prevention when the reservoir is not overfilled.^{21,23} In our modified Mainz pouch technique, both direct ureteral implantation into an

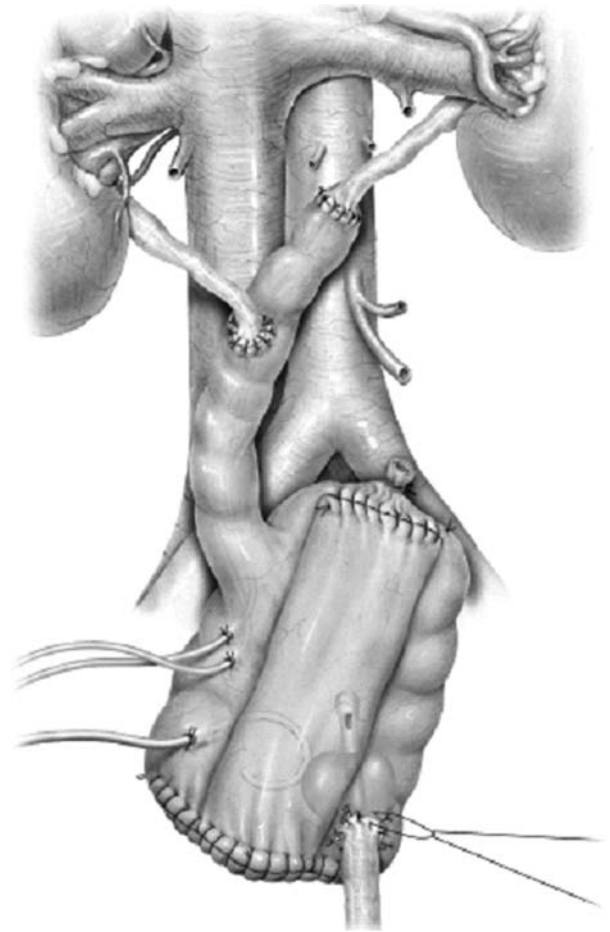


Figure 40.12 If ureters have to be resected short because of tumor extension or radiation damage, a longer segment of preterminal ileum can substitute both ureters. The length of the preterminal segment has to be chosen according to the length of the defect to be bridged by the ureteral substitute. From reference 18, with permission.

isoperistaltic ileal chimney and reflux prevention by the ileocecal valve are combined.²⁰

POSTOPERATIVE CARE

Antibiotics such as metronidazole and ampicillin/clavulanic acid are given at least 1 hour before surgery and are continued for 7–10 days. To avoid the discomfort of a nasogastric tube, we place a percutaneous 12 Fr balloon-gastrostomy catheter during surgery to drain the stomach for 3–5 days and have the patients drinking from the first postoperative day. If clamping of the gastrostomy is tolerated, the gastrostomy catheter is removed. Transurethral and percutaneous pouch catheters are irrigated every 2–4 hours to prevent plugging by mucus. Ureteral catheters are removed at the 9th or 10th postoperative day, and a

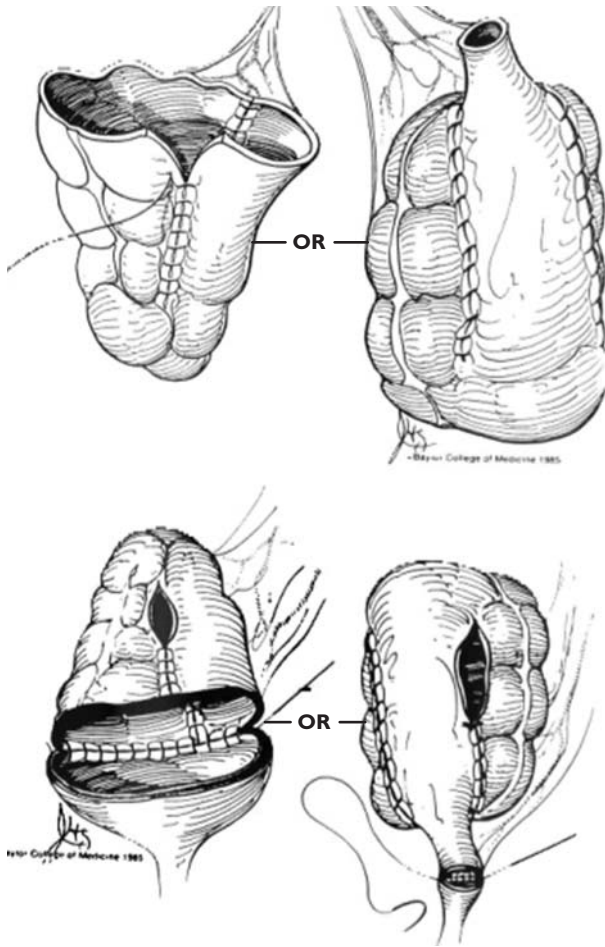


Figure 40.13 Le Bag technique. After isolation of the ileocecal segments, the bowel is split open completely for subtotal bladder substitution in benign diseases with anastomosis to the bladder remnant (left side). For urethrointestinal anastomosis in case of complete bladder substitution, the proximal 3–5 cm of ileum are left intact (right side). From reference 19, with permission.

subsequent intravenous pyelogram is performed to rule out extravasation. The transurethral catheter is removed when a pouchogram at the 12th postoperative day reveals absence of extravasation. When the patient starts voiding, instructions on how to contract the pelvic floor and urethral sphincter are provided by physiotherapists and an exercise program is initiated. If patients void without residual urine, the 10Fr percutaneous pigtail pouchostomy catheter is removed. However, one should be aware of the possibility of urinary extravasation from the pouchostomy tract. If this occurs re-insertion of a transurethral catheter becomes necessary for 1–2 days.

Before discharge from the hospital, base excess from arterialized ear lobe blood is checked. If base excess is lower than -2.5 mmol/l, alkali substitution is required

(in about 60% of patients) to reliably prevent clinical acidosis.

Follow-up examinations should be performed every 3 months during the first year including renal ultrasound, blood gas analysis, and blood chemistry. If follow-up is beyond 5 years, serum cobalamin should be determined and pouchoscopy be performed for early detection of secondary tumors.^{12,32,33}

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4 | Left colon neobladder

Avinash K Reddy and Pratap K Reddy

Bladder substitution with bowel segments following total cystectomy is an accepted procedure. A variety of bowel segments and configurations have been described for orthotopic bladder replacement following total cystectomy. This chapter details the use of the detubularized left colon for total bladder replacement (neobladder) in both men and women. Left colon neobladder (sigmoid neobladder) closely mimics the native bladder functionally. It provides an adequate low-pressure reservoir for storage and expulsion of urine under voluntary control. Antireflux ureteral implantation is possible and electrolyte imbalances are minimal.

PATIENT SELECTION

The most common indication to perform total bladder replacement is following radical cystectomy for locally invasive bladder cancer. Ideal candidates are those whose primary bladder cancer is located away from the bladder neck. The presence or extension of the tumor close to the bladder neck and/or multifocal carcinoma in situ of the bladder is a relative contraindication in men. Transitional cell carcinoma of the prostatic urethra or tumor at the distal urethral margin is an absolute contraindication. In women the presence of tumor at the bladder neck is a contraindication for total bladder replacement. Other indications include a crippled bladder or interstitial cystitis especially in women.

Patient motivation is the most important factor when considering bladder replacement. Generally, age and surgical risk should not significantly influence the surgeon's decision in considering bladder replacement as long as the patient is a suitable candidate to undergo radical cystectomy. Bladder reconstruction as compared with ileal conduit construction requires more time, but does not necessarily increase morbidity. Other factors to be considered when opting for a neobladder are obesity and renal insufficiency. Obese patients may not be ideal candidates for any surgical procedure, especially radical cystectomy; however, it has been my experience that these patients do extremely well following total bladder replacement as opposed to ileal conduit diversion with its associated stomal problems. The only limiting factor in these obese patients is whether the mesenteric length of the

bowel segment would allow for tension-free anastomosis to the urethral stump. The other important consideration is the patient's renal function. Normal renal function is essential to avoid metabolic problems due to intestinal reabsorption in the neobladder. Generally, a serum creatinine above 2.0 mg/dl would be an absolute contraindication to total bladder replacement using bowel segments other than stomach. Also, patients with progressive renal disease should be excluded even if their creatinine is normal.

Finally, a detailed discussion should be carried out with the patient and family so that they do not have any unrealistic expectations. The choice of the bowel segments to be used should be reviewed. As reconstructive surgeons we should approach this with an open mind. Following cystectomy the surgeon should be prepared to use either the left colon, right colon, ileum, or combinations thereof, based on the anatomic and functional limitations encountered during surgery.¹⁻⁴ This flexibility will minimize morbidity and ensure the best outcomes for the patients. They should also be informed that it could take up to 3 months or longer to achieve complete continence and even after that there is a possibility of both day and especially night time incontinence.

PREOPERATIVE PREPARATION

Patients undergoing total bladder replacement using the sigmoid colon require a barium enema or colonoscopy in addition to the standard evaluation prior to cystectomy. Malignancy of the colon excludes its use for bladder replacement. The presence of diverticula is not a contraindication; however, a long history of diverticulitis usually leaves the left colon unsuitable for bladder replacement. Bowel preparation on the day prior to surgery is important. All patients receive a mechanical bowel preparation with either GoLytely® or fleet Phospho Soda®. Prophylactic antibiotics are used routinely.

OPERATIVE TECHNIQUE

The patient is placed in the supine frog-leg position with the knees slightly flexed and adequately supported. This

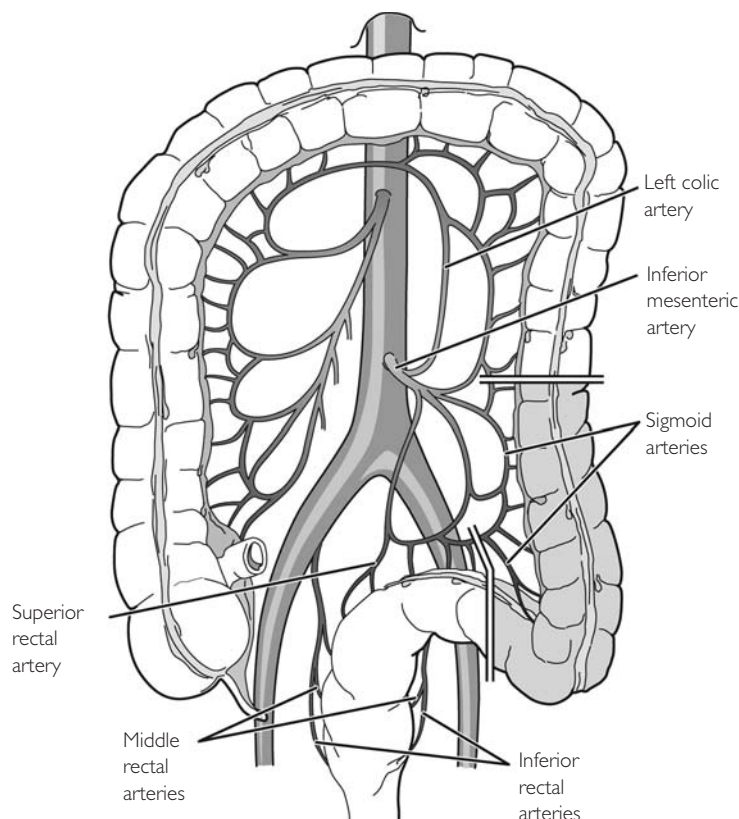


Figure 41.1 Isolation of the left colon on a broad mesenteric pedicle based on the sigmoid arteries.

position allows for easy access to the perineum to use the perineal push for better visualization of the urethral stump when performing the anastomosis. High-high intermittent pneumatic compression stockings are used. Radical cystoprostatectomy or anterior pelvic exenteration in the case of women is carried out in the standard fashion. During excision of the bladder pedicles on the left side, care is taken not to ligate the hypogastric artery as sometimes occurs during routine cystectomy. Also, dissection of the pelvic floor musculature is kept to a minimum and this may help with early return of continence. Frozen sections are obtained to confirm the absence of tumor at the distal urethral stump and both ureters.

There are several distinct steps involved in the construction of the left colon neobladder. Attention to detail throughout the procedure is essential. The steps include isolation of an adequate bowel segment with restoration of bowel continuity, construction of the detubular colon reservoir, antireflex ureterocolonic anastomosis, and, finally, completion of the neobladder.

A minimum of 30–35 cm of the left colon is needed to construct an adequate reservoir. If this is not available then the surgeon may opt for other bowel segments, because with a short segment, patients may have bothersome frequency, nocturia, and incontinence. It should be first determined that the mesentery

to the left colon neobladder is long enough to allow the colon to reach the pelvic floor without tension. This segment of the colon is isolated on a broad mesenteric pedicle based on the sigmoid arterial branches of the inferior mesenteric artery (Figure 41.1). The incision in the mesentery is kept short to avoid compromising the blood supply to the isolated segment. Colon continuity is re-established by end-to-end anastomosis of the colon using a single layer of interrupted 3-0 polyglactin (Vicryl) suture. Occasionally, the splenic flexure may have to be released to achieve a tension-free colonic anastomosis.

CONSTRUCTION OF LEFT COLON RESERVOIR

The isolated colon segment is brought medial to the colon and cleansed with antibiotic solution. It is then placed in the pelvis in a U-shape with the most dependent part of the U marked for later anastomosis to the urethral stump (Figure 41.2A). The entire colon segment is now incised along the medial tenia (Figure 41.2B). This allows for complete detubularization of the reservoir. The posterior edges of the opened colon segment are first aligned with a few interrupted 3-0 Vicryl sutures, and then approximated by a single

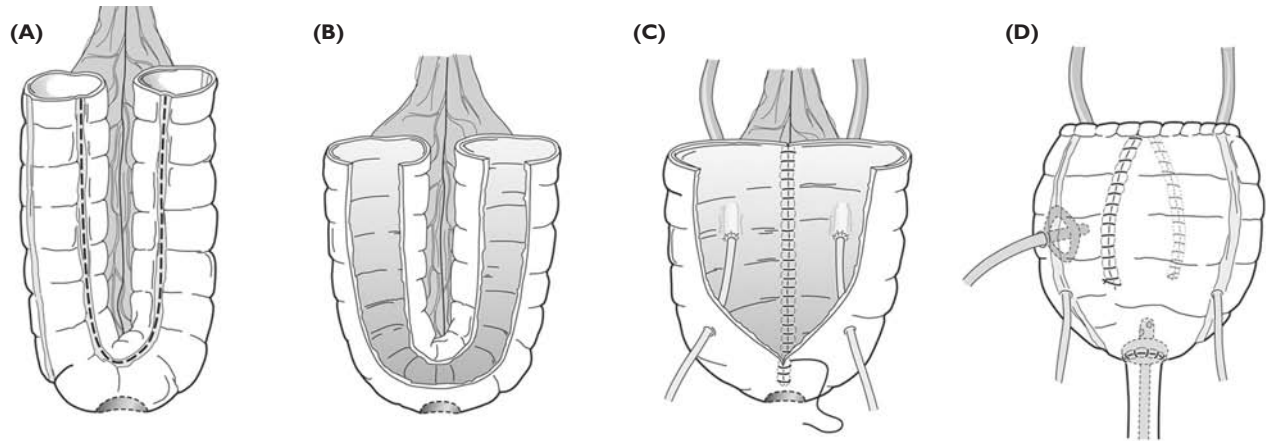


Figure 41.2 Construction of left colon neobladder. (A) The colonic segment is positioned in a 'U' with the most dependent part marked for anastomosis to the urethra. Dashed lines along the medial tenia indicate site of detubularization. (B) Colon segment detubularized. (C) Posterior layer is anastomosed. The ureters are implanted with submucosal tunnels and stented. Anterior and cephalic edges are subsequently closed. (D) Neobladder is completed by anastomosis to the urethra. Malecot and Foley catheter is placed for drainage. Ureteral stents exit anteriorly.

continuous suture of 3-0 Vicryl. I use a 3-0 Vicryl swedged on Keith needle to speed up the sewing process. This completes the posterior wall of the neobladder (Figure 41.2C).

The ureteral implantation is performed next. The left ureter is brought anteriorly through the colon mesentery. Both ureters are implanted into the posterior wall of the neobladder with interrupted 4-0 Vicryl sutures and antirefluxing submucosal technique is used (Figure 41.2C). This anastomosis is routinely stented using an 8 Fr infant feeding tube (an inexpensive surrogate for single-J stent), which is secured in place by transfixing it to the ureter with 5-0 chromic catgut suture. This usually dissolves in 2 weeks when the stents are ready to be removed. The stents are later brought through the anterior wall of the neobladder, through the anterior abdominal wall, and connected to drainage catheters to divert the urine. Next, the anterior wall of the neobladder is completed by approximating the anterior edges of the colon in a similar fashion to the posterior wall, using interrupted and running 3-0 Vicryl sutures. A 24 Fr Malecot catheter is inserted into the reservoir at a convenient location and the colonic reservoir is then completed by suturing the cephalad opening. The catheters are secured to the neobladder, the Malecot catheter with 3-0 chromic and the ureteral stents with 5-0 chromic catgut, to prevent dislodgement. The reservoir is then filled through the Malecot catheter and tested for leakage along the suture line and additional sutures placed if needed. The reservoir is now ready to be anastomosed to the urethral stump.

COMPLETION OF THE LEFT COLON NEOBLADDER

The next step is for the colonic reservoir to be anastomosed to the urethral stump in a fashion similar to the bladder being anastomosed to the urethral stump following radical prostatectomy. A small opening is made in the most dependent portion of the reservoir. Six interrupted sutures of 2-0 Vicryl are used for the anastomosis. A 20 Fr Foley catheter is placed per urethra (Figure 41.2D). The Malecot catheter and both infant feeding tubes are later brought out anteriorly through the abdominal wall in the right lower quadrant. A 15 Fr round Jackson-Pratt drain is placed in the pelvis and brought out through the abdominal wall in the left lower quadrant.

POSTOPERATIVE CATHETER CARE

The Malecot, Foley, and both ureteral stents are left to dependent drainage. The Malecot catheter is irrigated twice daily to evacuate any mucus from the neobladder. The ureteral and Foley catheters are irrigated only as needed. The ureteral and Foley catheters are removed on postoperative day 15. The patient is asked to clamp the Malecot catheter on day 21 and practice voiding for a week. The Malecot catheter is removed on day 28. No contrast studies are performed prior to removing the catheters. It has been our experience that 3 weeks is more than adequate for complete healing of the neobladder.

RESULTS

Use of the left colon for total bladder replacement has been reported by several authors.^{1,5-10} By 6 months the average capacity of the sigmoid neobladder ranges from 300 to 600 ml and the intrareservoir pressure at capacity ranges from 20 to 60 cmH₂O. Voiding frequency ranges between 3 and 5 hours. Based on the parameters used to define continence, daytime continence rates vary from 60 to 100%, and night time continence from 20 to 67%. Overall the night time incontinence remains high unless the patients wake up two or more times a night to void. Functional capacity and voiding patterns do not change appreciably after the first 6–12 months. Stricture rates from antireflex anastomosis are around 1.5–5%. No electrolyte imbalances have been noted other than a high normal serum chloride.

DISCUSSION

The left colon neobladder in the configuration described here has much to recommend it. First and foremost, it is technically simple and straightforward. Because of the large diameter of the colon, 30–35 cm of the colon is adequate to provide for a capacious low-pressure reservoir. Due to the redundancy of the sigmoid colon obtaining this length of the colon is usually possible. Some authors have described using a much shorter segment (18–20 cm) of the left colon to construct the neobladder.¹¹ This may result in less desirable voiding, urodynamic, and functional outcomes. If an adequate length of the left colon (at least 30 cm) is not available, I prefer to use alternate bowel segments. Due to its anatomic location, even after detubularization the sigmoid neobladder almost always reaches the correct position and provides for a nearly spherical reservoir with few suture lines, and no right-angle folding. A study comparing the construction and voiding functions of all the three types of neobladders, the right colon, the left colon, and ileum, concluded that there were no significant differences in operative time, blood loss, and functional results with these three types of neobladders.^{12,13} They did conclude that a centrally located, sigmoid neobladder achieved better voiding parameters.¹³ In other studies the authors found no significant difference in quality of life parameters between sigmoid and ileal neobladders.^{14,15} Finally, the sigmoid bowel segment is expendable with virtually no concerns about malabsorption problems (for example

vitamin B12, bile salts) or diarrhea as may occur with use of ileum or right colon.^{16,17} The left colon provides for an ideal bowel segment to perform neobladder. The choice of the ideal bowel segment to be used for neobladder should be determined intraoperatively based on the patient's anatomic considerations and the surgeon's preference and experience.

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42 Orthotopic urinary diversion in the female patient

Stephen A Boorjian and Michael L Blute

BACKGROUND AND INDICATIONS

Radical cystectomy continues to be performed for muscle invasive bladder cancer, superficial bladder cancer refractory to conservative measures, other pelvic malignancies requiring exenteration, and benign conditions resulting in what has been variously termed an 'end-stage bladder'. Currently, the spectrum of urinary diversions available to patients includes conduits of small and large bowel, continent cutaneous reservoirs, and orthotopic bladder substitution. Advantages of orthotopic neobladder reconstruction include the elimination of a cutaneous stoma or collection device, as well as the ability to preserve a near-normal volitional voiding pattern that allows patients to consciously void per the urethra at socially convenient intervals. These advances have been made in an effort to improve patients' lifestyle and self image following radical cystectomy. Indeed, Hobisch et al, using a validated quality of life questionnaire, found that patients with an orthotopic neobladder were more able to adapt to their new situation than patients with an ileal conduit, and that 97% of neobladder patients would recommend the same urinary diversion to a friend, compared with 36% of ileal conduit patients,¹ although a separate study found no differences in quality of life between patients with continent and conduit urinary diversions.²

Initially, the application of neobladder reconstruction in women following radical cystectomy was limited, largely due to perceptions that orthotopic diversion in women would be associated with increased risks of local (specifically, urethral) recurrence, as well as concerns regarding postoperative incontinence and voiding dysfunction.³ However, a better understanding of the natural history of transitional cell carcinoma in female patients, together with a better understanding of the neurovascular and fascial relationships of the female rhabdosphincter, has resulted in acceptance of orthotopic reconstruction in women.

In part, the increasing acceptance of orthotopic substitution in females has been the result of studies which have helped to further define the anatomy of the female urethral sphincter, as well as investigations

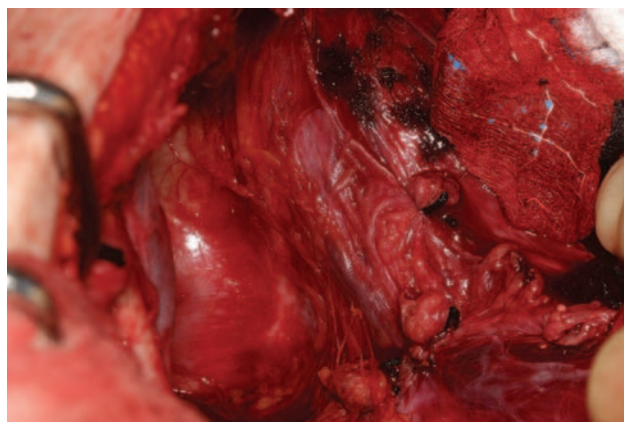


Figure 42.1 Intraoperative view of autonomic nerve fibers coursing along the lateral vaginal wall.

which have demonstrated the functional importance of the external striated sphincter, or rhabdosphincter, for maintaining continence in females following neobladder construction. Colleselli et al performed extensive microanatomic dissection, histologic examination, and three-dimensional computed tomography (CT) reconstruction of histologic sections to illustrate the urethral anatomy.⁴ These investigators established that the rhabdosphincter lies in the middle and caudal thirds of the urethra, primarily on the ventral and lateral aspects. In addition, they noted that the rhabdosphincter is supplied by branches of the pudendal nerve which run underneath the levator muscles after exiting the true pelvis through the greater sciatic foramen.⁴ These nerves, which lie deep to the endopelvic fascia, must remain functionally intact to provide continence after neobladder construction. However, continuity of the bladder and urethra has been determined not to be essential for closure of the striated urethral sphincter and subsequent urinary continence.

Moreover, the course of the autonomic fibers emerging from the pelvic plexus to innervate the pelvic visceral organs has been recently defined as well. These autonomic nerve fibers have been shown, using microanatomic dissection with the help of three-dimensional CT reconstruction of histologic sections,

to emerge from the pelvic plexus at the lateral margin of the rectouterine pouch and then course within a layer of connective tissue alongside the lateral walls of the vagina and uterus⁴ (Figure 42.1). The fibers enter the bladder neck as well as the cranial and middle thirds of the urethra.⁴ The functional significance of these fibers for continence has been debated;^{3,5} nevertheless, defining this pelvic neuroanatomy has facilitated the ability to spare these fibers during anterior exenteration by leaving the lateral vaginal walls intact. Additionally, improvements in the understanding of the urethral and bladder neck support structures have facilitated orthotopic neobladder reconstruction in females. Specifically, the role of the endopelvic fascia, anterior vaginal wall, and arcus tendinous fascia in the static support of the urethra, as well as in limiting the downward excursion of the bladder neck, have allowed technical modifications during cystectomy and reconstruction to improve continence and emptying in women following orthotopic neobladder substitution.⁶

In addition to defining the neuroanatomy and fascial support system of the female urethra and sphincter, identification of risk factors for urethral tumor involvement in women with transitional cell carcinoma of the bladder has helped to establish orthotopic neobladder as a valid form of bladder substitution in women. In particular, studies have aided in appropriately selecting female patients in whom reconstruction to the native urethra can be performed without compromising cancer control. For example, Stein et al performed a pathologic review of 67 consecutive female cystectomy specimens and demonstrated that the urethra could be safely preserved in the majority of women undergoing cystectomy.⁷ Specifically, histologic evidence of tumor (carcinoma in situ or gross carcinoma) involving the urethra was found in nine patients (13%). Importantly, all patients with carcinoma involving the urethra had concomitant evidence of carcinoma involving the bladder neck, and, conversely, all patients with an uninvolved bladder neck also had an uninvolved urethra.⁷ Similarly, Stenzl et al evaluated 356 women treated for bladder cancer and found that, while only 1% of patients with clinically localized, invasive bladder cancer who would have been considered for orthotopic neobladder diversion had urethral tumor involvement, all patients with urethral tumor involvement had tumor at the bladder neck as well, a correlation which was highly significant.⁸ In fact, this study identified tumor at the bladder neck as the only significant and consistent risk factor for concomitant urethral involvement. The authors further speculated that this low incidence of

urethral tumors in women, which is in fact lower than the reported incidence of urethral involvement in men, may be the result of the fact that transitional cell mucosa in women covers a much smaller area than in men, with the remainder being normal or metaplastic squamous cell mucosa.⁸

Based on the findings from these studies, bladder neck tumor involvement has been consistently identified as a risk factor for urethral disease. It should be noted, however, that not all patients with tumor at the bladder neck have been found to have urethral tumor involvement; approximately 50% of patients with tumor involving the bladder neck did not have cancer in the urethra.⁷ In addition, intraoperative frozen section analysis of the distal surgical margin has been shown to be an accurate and reliable method to evaluate the proximal urethra for tumor. In particular, intraoperative frozen section prospectively evaluated the proximal urethra correctly in all of 29 specimens removed for transitional cell carcinoma, as confirmed by final pathology.⁵ Thus, even women with tumor at the bladder neck can be considered candidates for orthotopic reconstruction if the intraoperative frozen section margin of the urethra is found to be negative.

It should be noted that, multifocal carcinoma in situ of the bladder, which had been previously thought to be a contraindication to neobladder creation in women, was not found to be a significant predictor of carcinoma found in the urethra by Stein et al, despite the fact that 30% of patients with carcinoma in situ had tumor involving the bladder neck.⁷ On the other hand, anterior vaginal wall tumor involvement has been shown to be a risk factor for urethral disease, with 50% of these specimens demonstrating urethral involvement with tumor.⁷

In our practice, contraindications to orthotopic neobladder creation include patients with an intraoperative frozen section of the distal urethral margin that is positive for cancer, as well as patients who are unable or unwilling to perform self-catheterization, patients with impaired renal function, and patients with insufficient ileum for use, due to either inflammatory bowel disease or previous surgical resection.

SURGICAL TECHNIQUE

The technique for radical cystectomy in women has traditionally involved en bloc removal of the bladder with its peritoneal coverings, the urachal remnant, the entire urethra including the external meatus, uterus, fallopian tubes, ovaries, and anterior vaginal wall. In

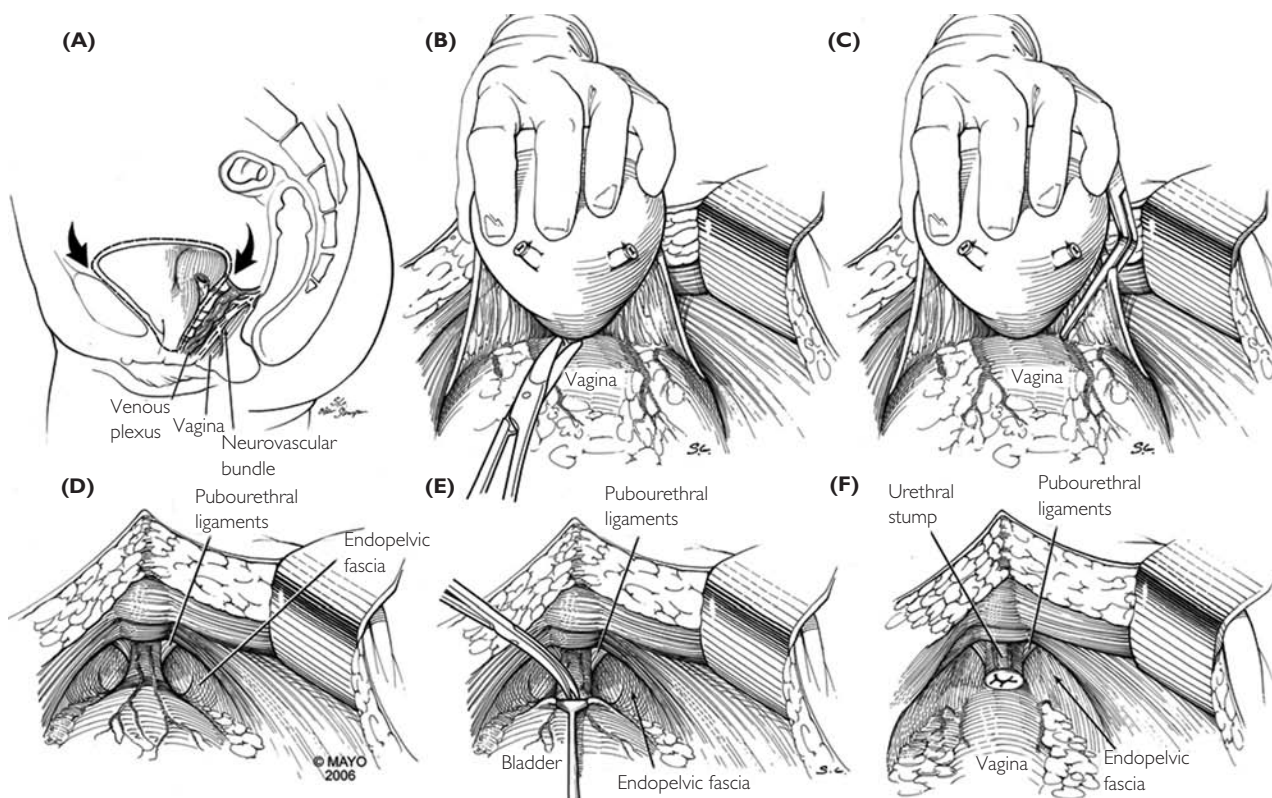


Figure 42.2 Sequence of radical cystectomy in a woman prior to orthotopic diversion. (A) Sagittal view of female pelvis, with arrows indicating planes of dissection anteriorly beneath the pubic bone and posteriorly above the anterior vaginal wall. (B) Anterosuperior view of pelvis, demonstrating 'vaginal sparing' technique of dissecting between the bladder and the anterior vaginal wall. (C) After the posterior plane has been completed down to the bladder neck, the posterolateral bladder pedicles are ligated. (D) Anterosuperior view of the pelvis, demonstrating an intact endopelvic fascia and pubourethral ligaments. (E) Division of the anterior urethra at the bladder neck, using a vein retractor to help retract the bladder and preserve maximal urethral length. (F) Anterosuperior view of the pelvis after the bladder has been removed, with preservation of the endopelvic fascia, pubourethral ligaments, and anterior vaginal wall. Mayo Clinic. All rights reserved. Reprinted with permission.

addition, the value of an extended pelvic lymph node dissection in patients with transitional cell carcinoma who undergo radical cystectomy has been well established and should be standard. Here, we highlight several aspects of the procedure as they apply to preparation for orthotopic urinary diversion. In particular, since continence following orthotopic neobladder creation is dependent upon an intact rhabdosphincter, strict attention to anatomic detail is necessary to preserve the proximal urethra, external urethral sphincter, and associated supporting tissues.

The first step of our technique involves incising the peritoneal fold between the bladder and uterus to allow dissection of the bladder off the anterior vaginal wall (Figures 42.2 and 42.3). This plane is carried down to the level of the posterior bladder neck using a combination of sharp dissection and electrocautery. Dissection is aided by palpation of the Foley catheter balloon and superior traction on the bladder. With this technique the uterus may be preserved, in which case the plane between the bladder and anterior vaginal wall

is started just distal to the cervix.⁹ Alternatively, a hysterectomy may be performed, and the vaginal cuff oversewn with absorbable suture⁹ (Figure 42.4) and then covered with peritoneum reflected from the anterior rectal wall.¹⁰ In either case, we believe that preservation of the anterior vaginal wall decreases the risk of neobladder-vaginal fistula and improves continence following orthotopic reconstruction by providing support for the neobladder and helping to prevent rotational descent. In addition, maintaining vaginal vault length may contribute to improved functional outcome in patients who are sexually active.⁹ However, appropriate patient selection is essential to not compromising cancer control by sparing the anterior vaginal wall. We, as others,⁹ do not recommend a vaginal-sparing approach in patients who have, for example, a palpable tumor with suspected invasion of the anterior vaginal wall. This does not necessarily preclude neobladder reconstruction, as we have performed orthotopic diversion after anterior vaginal wall excision with vaginal reconstruction.

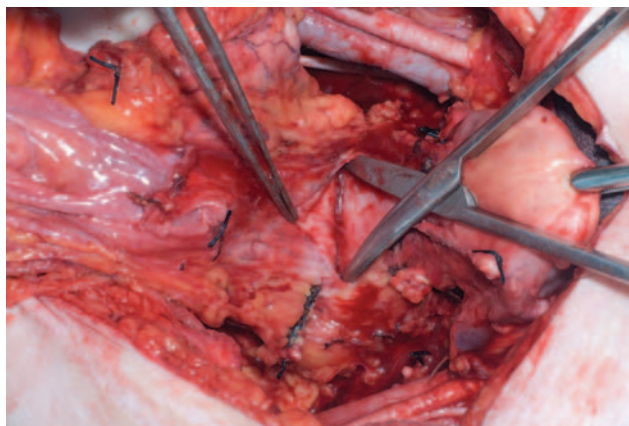


Figure 42.3 Incision of peritoneal fold between bladder and uterus to establish plane of dissection of bladder off anterior vaginal wall.

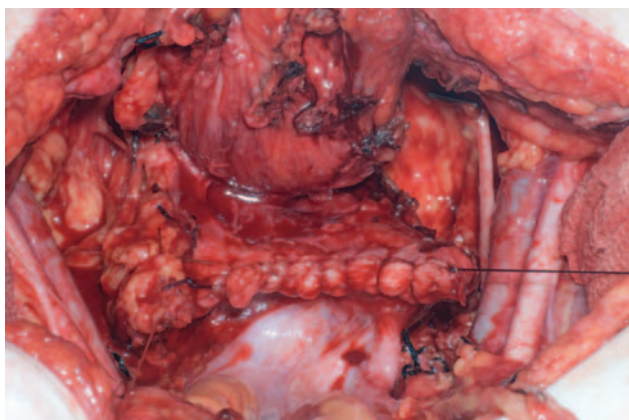


Figure 42.4 Closure of vaginal cuff after hysterectomy with running, absorbable suture.

Once the posterior aspect of the bladder neck and urethra have been identified, the lateral and posterior bladder pedicles are ligated and divided down to the level of the anterior vaginal wall (Figure 42.2C). Care is taken during ligation of the bladder pedicles to spare the lateral vaginal walls, and thereby preserve the autonomic neurovascular bundles which course along the lateral aspect of the uterus and vagina to innervate the bladder neck and proximal urethra (Figure 42.1). Although excellent continence rates have been reported by surgeons who routinely sacrifice these nerves with the belief that the rhabdosphincter, innervated by pudendal nerve branches which lie deep to the endopelvic fascia, will provide continence,⁵ we believe, as has been reported elsewhere,³ that this autonomic innervation has functional significance in enhancing coordinated voiding.

Importantly, dissection anterior to the bladder neck and urethra during the radical cystectomy should be minimized in order to preserve the nerve supply to the

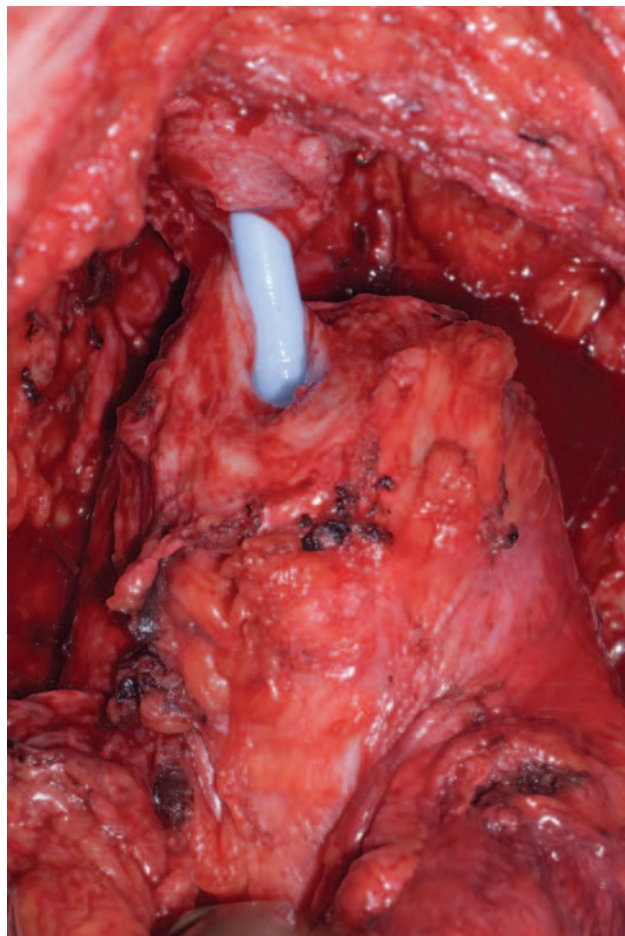


Figure 42.5 Division of anterior urethra down to catheter. Note the generous stump length of urethra to facilitate anastomosis to neobladder neck.

rhabdosphincter and the pubourethral suspensory ligaments, which provide support to the rhabdosphincter and are essential in maintaining urinary continence after orthotopic reconstruction (Figure 42.2D). Thus, the endopelvic fascia, which provides a covering to these nerves and sits in continuity with the suspensory ligaments, is left intact.

At this point, the specimen remains attached only by the urethra. The bladder often hangs over the proximal urethra; therefore, to preserve maximal urethral length, a vein retractor may be used to help retract the bladder and expose the anterior urethra (Figure 42.2E), which is then divided at the bladder neck down to the catheter (Figure 42.5). After the catheter is withdrawn, the posterior urethra is incised, and the fibromuscular tissue attached to the perineal body and urethra are divided, freeing the specimen (Figure 42.2F).

After the bladder has been removed, some surgeons place an omental pedicle graft, created on the left gastroepiploic artery, over the anterior vaginal wall,

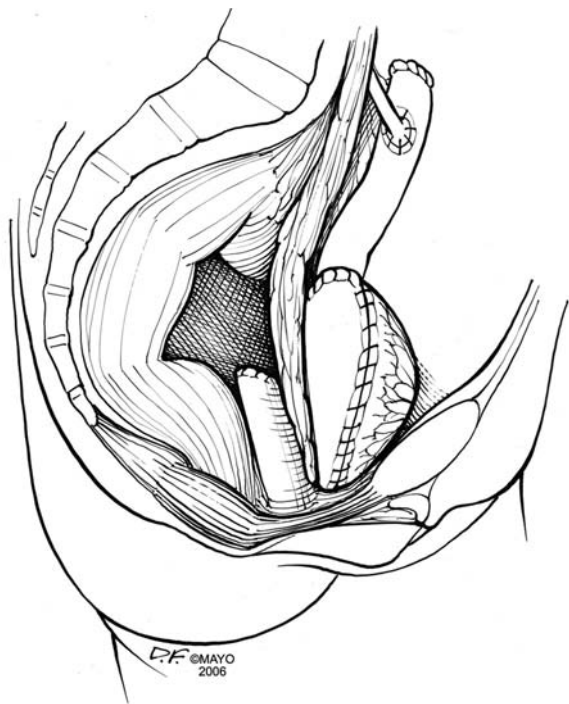


Figure 42.6 Omental flap utilized by some surgeons to separate vaginal and neobladder suture lines and to provide additional pelvic support for neobladder. Mayo Clinic. All rights reserved. Reprinted with permission.

particularly if vaginal reconstruction has been required, and secure this piece of omentum to the levator ani muscles (Figure 42.6). The graft separates the suture lines of the vagina and neobladder (particularly following concurrent hysterectomy or repair of inadvertent entry into the anterior vaginal wall), and may thereby help to prevent fistulization, which has been reported in 4–7% of cases.^{9,10} In addition, the use of omentum has been suggested as a way to prevent the descent of the neobladder dorsal and caudal to the neovesicourethral anastomosis. This phenomenon, which is analogous to a cystocele of the native bladder, has been termed ‘pouchocoele’, and has been cited as a cause of mechanical outlet obstruction in women following orthotopic diversion.¹⁰ The resulting ‘pouchocoele’ has been cited as a cause of difficulty emptying and increased residual urine which occurs in a subset of women after neobladder reconstruction, also termed ‘hypercontinence’.⁶

Alternatively, it has been suggested that pelvic organ descent and resultant prolapse may be prevented by preservation of the anterior vaginal wall during cystectomy.⁹ While we do not routinely employ an omental flap to support the neobladder in women, after the bladder has been removed, we do routinely perform a culdoplasty prior to orthotopic reconstruction, in which

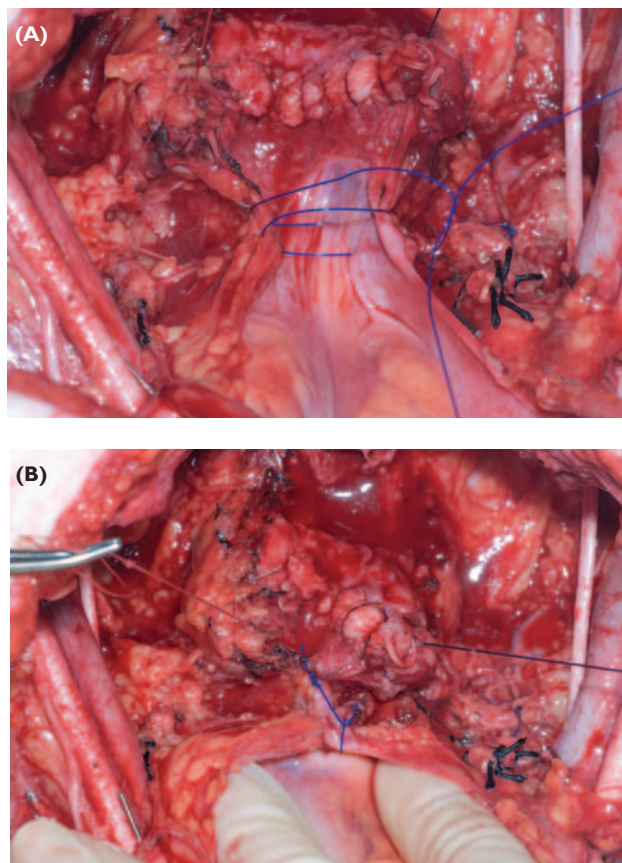


Figure 42.7 Intraoperative view of culdoplasty. (A) Uterosacral ligaments plicated using permanent sutures in figure-of-eight fashion. (B) Completed culdoplasty, with the sutures tied down so as to allow a space for two fingers to fit beneath the ‘shelf’ of the plicated ligaments, in order to prevent compromise of the sigmoid colon. Closed vaginal cuff is seen resting on the plicated ligaments.

the uterosacral ligaments are plicated together with permanent sutures (Figure 42.7), creating a support plate for the neobladder to rest on that helps prevent postoperative prolapse with its potential impact on voiding/continence.

After extended pelvic lymphadenectomy, the neobladder is then constructed by configuring a low-pressure detubularized ileal segment into a sphere, in combination with an afferent, tubular isoperistaltic limb. We utilize an approximately 55 cm segment of terminal ileum for the neobladder, taken starting approximately 25 cm proximal to the ileocecal valve (Figure 42.8A), after ensuring that the midportion of the segment to be isolated reaches the urethral stump without tension. Ileal continuity is re-established, the left ureter is brought under the sigmoid mesentery, and the ureters are spatulated and re-implanted in a standard Bricker fashion to the proximal end of the afferent limb using a double-armed 5-0 absorbable suture in a running fashion. The

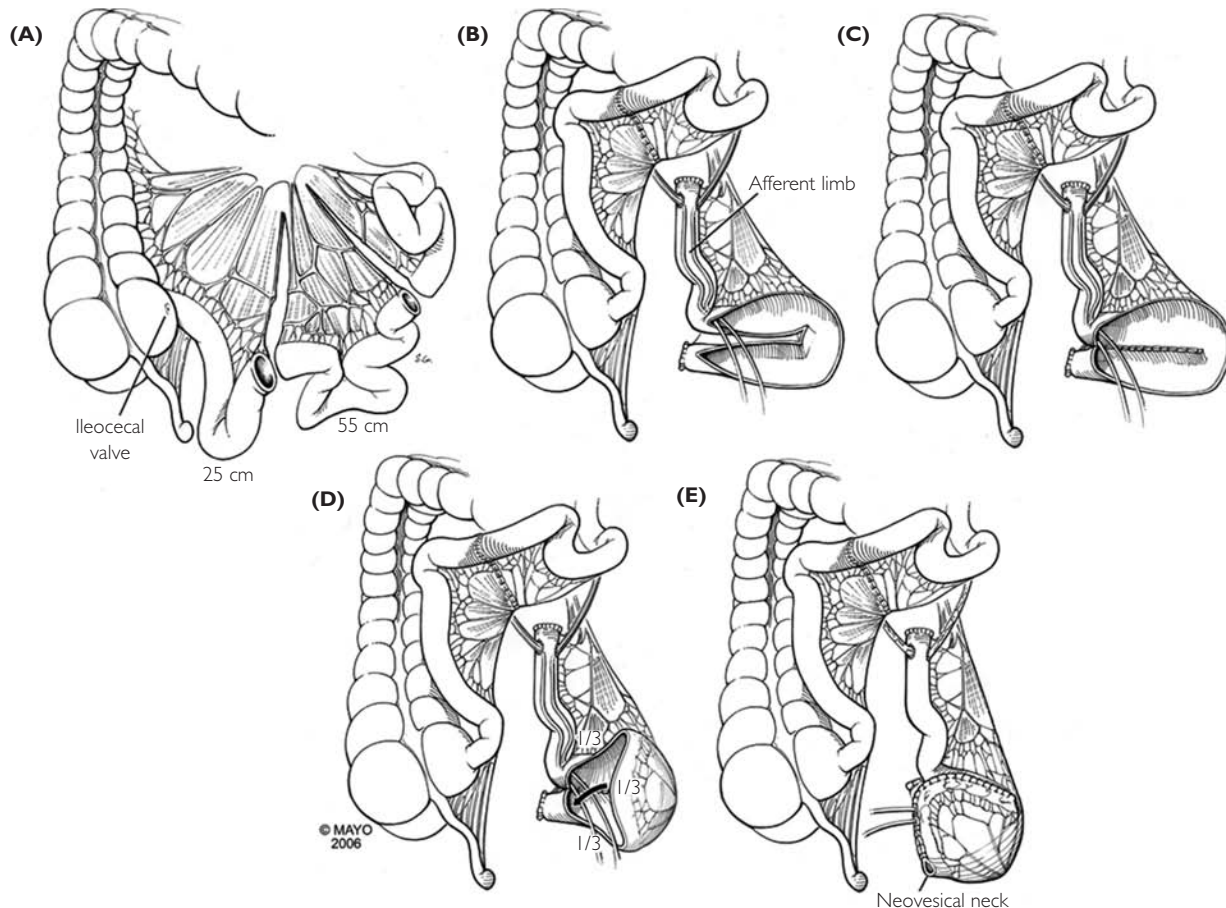


Figure 42.8 Creation of the ileal neobladder. (A) A 55 cm segment of terminal ileum is isolated approximately 25 cm from the ileocecal valve. (B) After the ureters are plugged into the proximal end of the ileal segment, which will remain intact and serve as an afferent limb, the distal 40 cm of isolated ileum are detubularized along the antimesenteric border and folded into a 'U' shape. (C) The posterior wall of this 'U' is then closed. (D) The neobladder is then folded approximately one-third : two-thirds to form a sphere, and the anterior wall is closed. (E) Completed pouch, with ureteral stents brought out through the side wall, and the inferior aspect of the suture line left intact to serve as the neobladder neck for anastomosis to the urethra. Mayo Clinic. All rights reserved. Reprinted with permission.

ureterointestinal anastomoses are completed over a single-J stent, which is secured to the mucosa of the neobladder using a chromic suture. As volitional voiding in patients with a neobladder is accomplished through the Valsalva maneuver, where the pressure within the renal pelvis, the ureters, and the neobladder increases uniformly, we do not believe that non-refluxing anastomoses are necessary.

The proximal 15 cm of this isolated segment where the ureters have been re-implanted is then left intact as an afferent limb, while the distal 40 cm are detubularized on the antimesenteric border and folded into a 'U' shape (Figure 42.8B). The posterior wall of the pouch is closed in a single seromuscular layer using a running, locking Vicryl suture (Figure 42.8C). The 'U' shaped segment is then folded as shown (Figure 42.8D) to form a spherical pouch, and the anterior wall of the neobladder is similarly closed with a running, locking Vicryl suture. The ureteral

stents are brought out through the side wall of the neobladder (Figure 42.8E).

As the anterior wall of the neobladder is closed, a finger is introduced through the remaining opening of the reservoir to determine the most dependent portion, which will serve as the site for the neovesicourethral anastomosis. A hole is cut in this dependent portion of ileum, away from the suture line, to create a neobladder neck. For neobladder reconstruction in women, we perform a running urethroneobladder anastomosis, using a double-armed Monocryl suture, as we have found that the urethral stump in females is reachable without difficulty, and the running anastomosis is consistently watertight. One arm of the suture is first put in at the 6 o'clock position in the urethral stump, which is identified with the help of a urethral sound, and then in its corresponding position in the bladder neck and tied down to bring the neobladder into the pelvis at the

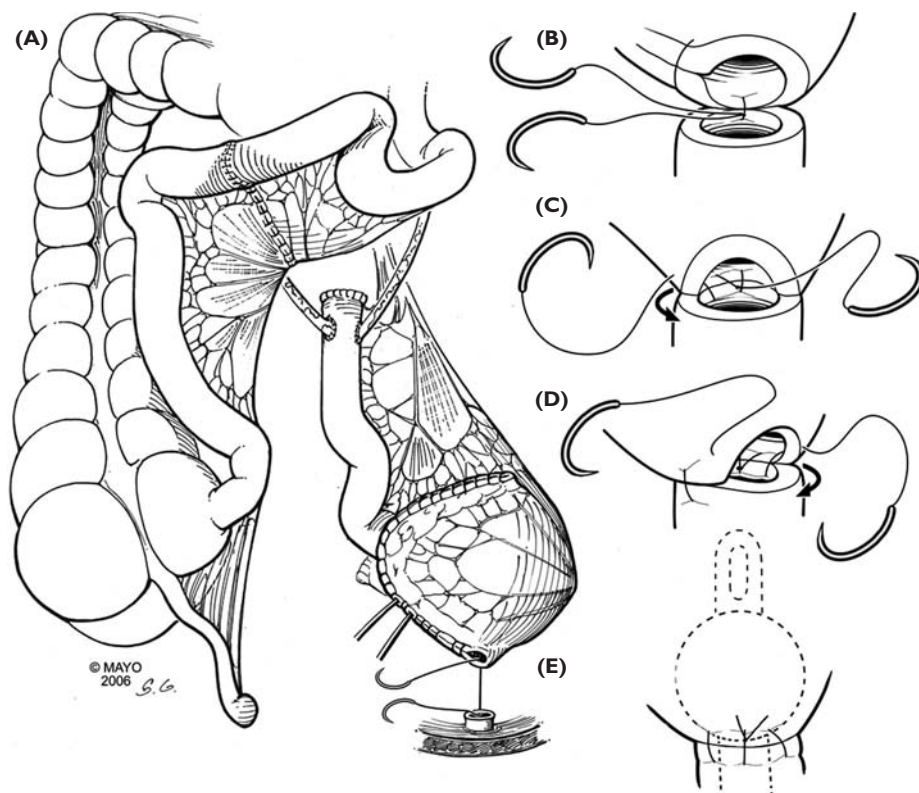


Figure 42.9 Anastomosis between urethra and neobladder. (A) and (B) A single, double-armed suture is placed at 6 o'clock into the urethral stump and neobladder neck and then tied down. (C) The left arm of the suture is run from 6 o'clock to 12 o'clock on the left side of the anastomosis. (D) The right arm of the suture is then run from 6 o'clock to 12 o'clock on the right side of the anastomosis. (E) The anastomosis is then tied down at 12 o'clock over a Foley catheter, and the balloon is inflated. Mayo Clinic. All rights reserved. Reprinted with permission.

level of the urethral stump (Figure 42.9). Then, one anastomotic suture arm is run from the 6 o'clock to the 12 o'clock position on the left side of the anastomosis, while the second arm of the suture is run from 6 o'clock to 12 o'clock on the right side of the anastomosis (Figure 42.10). Prior to tying the anastomotic sutures, a sound is passed antegrade through the urethra, out of the meatus, and tied to a fresh 20Fr Foley catheter, which is then guided into the neobladder. The two arms of the suture are tied together at the 12 o'clock position, and the anastomosis tested for extravasation by irrigating the urethral catheter. A suprapubic catheter is not routinely used.

The ureteral stents are secured to the skin and placed to an ostomy drainage bag. A small suction drain is left in the pelvis, and the incision is closed.

POSTOPERATIVE MANAGEMENT AND FOLLOW-UP

Catheter irrigation is begun with 60 ml of saline three to four times daily beginning immediately postoperatively to evacuate mucus. Diet is advanced as bowel function recovers. Once the patient has tolerated a regular diet, the stents are removed, and, as long as the drain output does not change appreciably after stent

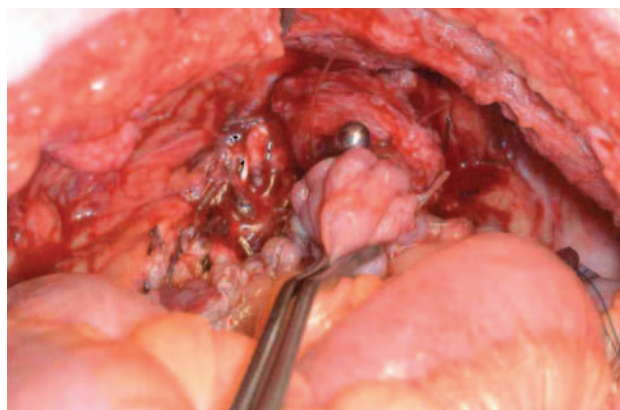


Figure 42.10 Intraoperative appearance of running anastomosis with double-armed suture, run on each side from the 6 o'clock to 12 o'clock position. Sound identifies urethral stump.

removal, the drain is removed on the next day and the patient is discharged home with the Foley catheter to straight drainage.

The catheter is left in place for a total of 21 days. On postoperative day 21, the patient returns for a cystogram; as long as no leakage is observed from the neobladder or from the urethral anastomosis, the catheter is removed for a voiding trial, and the patient is instructed to drink 2–3 liters of fluid per day to

ensure sufficient hydration to avoid salt loss and acidosis from hypovolemia. During the ensuing 3–6 months, bladder capacity is expected to increase to approximately 500 ml. At 8 weeks postoperatively, residual urine is determined by bladder ultrasound; if the residual urine is greater than 150 ml, patients are instructed on timed voiding and double voiding. If the result is greater than 250 ml, self-intermittent catheterization is initiated. All patients undergo complete urodynamic evaluation at 12-month follow-up. Voiding cystography is also performed to determine the efficiency of neobladder evacuation.

During the first year after surgery, tumor surveillance is performed at quarterly intervals with chest roentgenography, CT scans of the abdomen and pelvis, and voided urinary cytology. Cystoscopy is not performed routinely unless recurrence is suggested by imaging or cytology.

RESULTS

The application of orthotopic neobladder construction after radical cystectomy in women has occurred after clinical and pathologic studies helped to establish the natural history of transitional cell carcinoma in female patients and further elucidate the neurovascular and fascial relationships of the female rhabdosphincter. Nevertheless, concerns remain regarding the oncologic and functional outcomes of this relatively new approach to urinary diversion. With regard to tumor recurrence, a recent prospective study involving 145 women who underwent radical cystectomy and orthotopic bladder substitution, with a mean follow-up of 36 months, reported oncologic failure in the form of local recurrence and/or distant metastasis in 36 patients (24.8%).¹¹ Oncologic failure was noted to correlate with pathologic tumor stage, grade, and lymph node status. However, only two patients (1.4%) from this series experienced isolated urethral recurrence after neobladder, and thus the authors concluded that such a low rate of recurrence justified orthotopic diversion for women in carefully selected patients.¹¹

Meanwhile, the reported rates of urinary continence following neobladder reconstruction in women, while excellent, have varied somewhat between surgical series, likely reflecting different surgical techniques, as well as differing definitions of continence. For example, Ali-El-Dein et al reported a series of 60 women who underwent cystectomy with orthotopic diversion, with follow-up available in 43.¹⁰ Complete continence (without the need for pads or medication) was found

in 32 out of 43 (74%) women, while six out of 43 (14%) experienced night-time incontinence, two patients had stress urinary incontinence, and one patient was totally incontinent.¹⁰ Similarly, a separate surgical series reported continence, defined as requiring one pad or less per day, in 15 of 21 (71%) patients.⁹ Another investigation, of 15 female patients, found 100% of women continent during the day and 89% continent at night at a median follow-up of 19 months after orthotopic bladder substitution.³ Meanwhile, Stein et al reported complete daytime continence in 28 of 33 (85%) patients evaluated, with complete night-time continence in 27 of 33 (82%) patients.⁵ Likewise, we demonstrated a daytime continence rate of 86.7%, with night-time continence in 60% of patients, during our early experience.⁶ We have since updated these results, and have noted daytime continence in 90% of women, with night-time continence in 77% (Boorjian and Blute, unpublished data). In addition, all upper urinary tract imaging studies from our experience have shown stable function, while urodynamic studies have revealed high-compliance, large volume (470–1200 ml) neobladder capacities.

Complication rates following orthotopic reconstruction in women have been reported to be between 9 and 24%,^{5,9,10} and have consisted primarily of postoperative ileus. In our experience to date with orthotopic reconstruction in 66 women, we have noted a perioperative complication rate of 18%, including ileus or small bowel obstruction in 6%, and a need for reoperation in 6%. We have seen late complications in 14% of females after neobladder reconstruction, which have consisted primarily of metabolic acidosis (6.7%), renal insufficiency (3.7%), and ventral hernia (3.7%) (Boorjian and Blute, unpublished data). Neobladder-vaginal fistula has been reported to occur as well,^{9,10} although successful transvaginal repair has been demonstrated.¹⁰ Moreover, difficulty emptying the pouch spontaneously (or ‘hypercontinence’), with the subsequent need for self-catheterization, has been reported in 9.5–40% of females after orthotopic urinary diversion,^{5,6,9,10,12} including 25% of women from our series (Boorjian and Blute, unpublished data).

Overall, a better understanding of the natural history of transitional cell carcinoma in women, as well as of the anatomic and functional relationships of the female rhabdosphincter, has facilitated increased application of orthotopic neobladder reconstruction in female patients. Although results from reported series to date contain a relatively limited number of patients, with continued adherence to surgical technique and appropriate selection of patients, long-term results are

likely to parallel those reported after orthotopic diversion in men.

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43 Supravesical urinary diversion: conduits

Amit R Patel and Amr Fergany

INTRODUCTION

The need for urinary diversion arises in the patient with urologic/gynecologic malignancy, urologic malfunction, congenital malformation, or inflammatory disorders of the lower urinary tract with either irradiation or immunologic etiology. Over the past 150 years, the methods of supravesical urinary diversion have changed vastly with the exception of one mainstay, the use of bowel in urinary diversions. From ureterorectal ligations for bladder exstrophy by Sir John Simon in 1851, then Boari's mechanical button in 1895 to avoid ureteral stenosis, to Madyl's intraperitoneal bladder trigone reimplantation into the sigmoid, many techniques have been tested and have undergone evolution or extinction. Uretersigmoidostomy was popularized after Coffey's description in 1911 of tunneling the ureters into the bowel. However, its popularity was overtaken by Bricker's reintroduction of ileal conduit in 1950 as a diversion with fewer complications and greater technical feasibility.¹ Today, urologic surgeons can choose from an arsenal of urinary diversions including non-continent conduits, continent orthotopic neobladders, and pouches with continent cutaneous catheterizable stomas.

When deciding on the proper type of diversion, the surgeon and patient must analyse the multiple factors that weigh into the overall outcome of the urinary diversion. A non-continent diversion is essentially a disarticulated bowel segment to which the ureters are attached proximally and contains a stoma distally. Due to its wide applicability among urologic disorders, its tolerability in patients with significant comorbidities, and its anatomic adaptability, the conduit remains the most common form of urinary diversion performed.² **This chapter discusses the operative techniques, indications, and complications of three common types of urinary conduits: ileal-jejunal conduit, ileocecal conduit, and colonic conduit.**

ILEAL CONDUIT

The first attempt to divert urine into an isolated segment of ileum was done by Verhoogen in 1906. The

ureters were anastomosed to an isolated ileocecal segment with the urine flowing out of the appendix. The ureteroileal cutaneous diversion was first described by Seiffert in 1935. Due to the technical difficulty to effectively collect and store urine, the procedure was not continued. However, since Bricker re-described the procedure in 1950, it has gained widespread acceptance worldwide.³ The ileal conduit is the fastest and simplest conduit to construct and it is the simplest to take care of. Any segment of ureter can be attached to the conduit from the renal pelvis to the trigone. In addition, advances in enterostomal treatment and therapy have increased the durability and tolerance of the ileal conduit.

Indications

Any patient requiring urinary tract reconstruction following extirpative pelvic surgery may be considered for an ileal conduit. It can also be used in cases where the bladder is left in situ, for example, in neurogenic bladder, although modern management of neurogenic bladder has limited the role of supravesical diversion for this indication. The patient should be informed about all types of urinary diversions prior to choosing an ileal conduit. However, the decision to choose the type of urinary diversion also relies heavily on the clinical condition of the patient, their comorbidities, body habitus, disability, and any other systemic illness that may preclude them from other types of urinary diversions.

Preoperative preparation

Preoperative preparation of the patient includes a regimen of clear liquid diet starting 1–2 days prior to surgery, followed by a 4 liter preparation of polyethylene glycol on the afternoon before surgery. This mechanical preparation has largely replaced antibiotic bowel preparation regimens. Patients with indwelling urinary catheters or colonized urinary tracts are admitted the day prior to surgery for broad spectrum intravenous antibiotics which continue postoperatively for approximately 3–5 days.

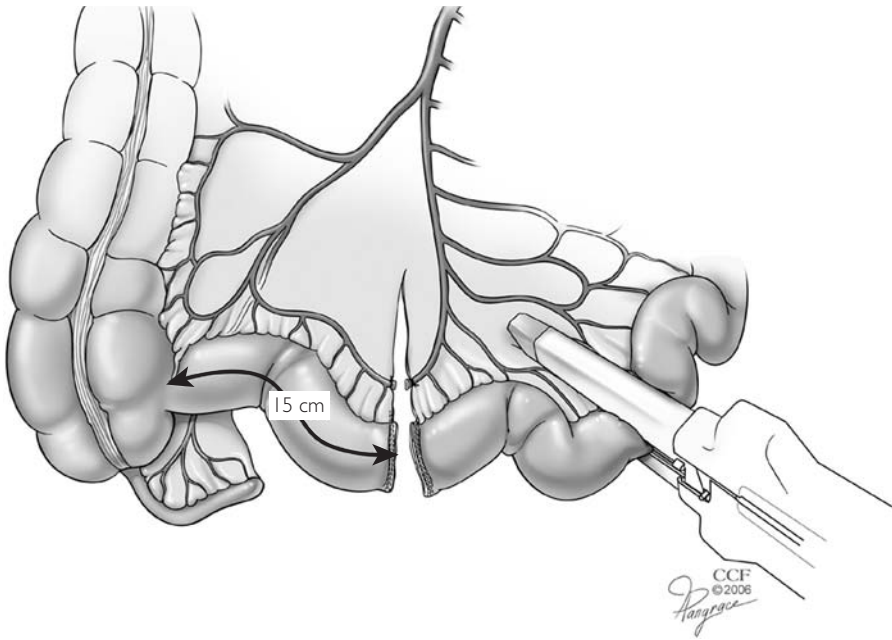


Figure 43.1 An ileal segment 15 cm proximal to the ileocecal valve is isolated and placed caudally to the anastomosis of the small bowel. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

The stoma site should be determined preoperatively in all patients by an enterostomal nurse or specialist. Patients are examined in the supine, sitting, and standing positions. The umbilicus, belt line, bony protuberances, prior surgical scars, and skin folds are noted and avoided when choosing the stoma site. The ideal stoma site is usually just medial to the linea semilunaris between the umbilicus and the anterior superior iliac spine. In obese patients, placement of the stoma site at a slightly higher level than usual may be beneficial as visualization of the stoma site is important for appliance positioning by the patient. The stoma site is usually marked with indelible ink prior to surgery.

Operative technique

The patient is placed in the supine position with the table flexed approximately 10° to provide optimal pelvic exposure. A low midline incision from the pubis to the umbilicus or beyond is sufficient to provide exposure for the cystectomy and/or pelvic exenteration including dissection of the ureters and mobilization of the bowel for the conduit. The incision is smaller if the diversion is being performed alone. The posterior peritoneum is incised at the pelvic inlet to expose the ureter coursing over the vessels. The ureters are dissected to the bladder and transected as close to the bladder as possible. Care should be taken not to dissect the adventitia and surrounding periureteral soft tissue off the ureter to prevent the loss of vasculature to the distal ureter. Although the distal

end of the ureter can be clipped to allow for the ureter to dilate while the remainder of the procedure is completed, we prefer to leave the ureters draining freely.

The terminal ileum is identified and examined for radiation enteritis, inflammatory bowel disease, malignancy, and length. If favorable conditions exist, a point on the terminal ileum 10–15 cm proximal to the ileocecal valve is identified and marked with a stay suture. A 15–20 cm measured length of bowel proximal to the first stay suture is marked with another stay suture. The stay sutures define the proximal and distal ends of the conduit. The optimal length of conduit differs in each case due to patient body habitus and length of available ureter. It is recommended that the length of conduit does not exceed the distance between the sacral promontory and the stoma site. The mesentery is transilluminated to inspect the blood supply to the conduit. In examining the mesentery, it is important to spare the ileocecal artery and to ensure that at least two vascular pedicles in the base are identified for division. An incision is made in the peritoneum over the mesentery and the mesenteric vessels are clamped and tied. It is important to recognize that the length and mobility of the segment that is to reach the skin is only dependent on the distal mesenteric division; thus the proximal mesenteric division should be short, allowing for a broad vascular pedicle to the conduit (Figure 43.1).

The bowel is then divided using a linear gastrointestinal anastomosis (GIA) stapler. The conduit is placed caudal to the remainder of the bowel. The mesenteric window is closed using interrupted 3-0 silk

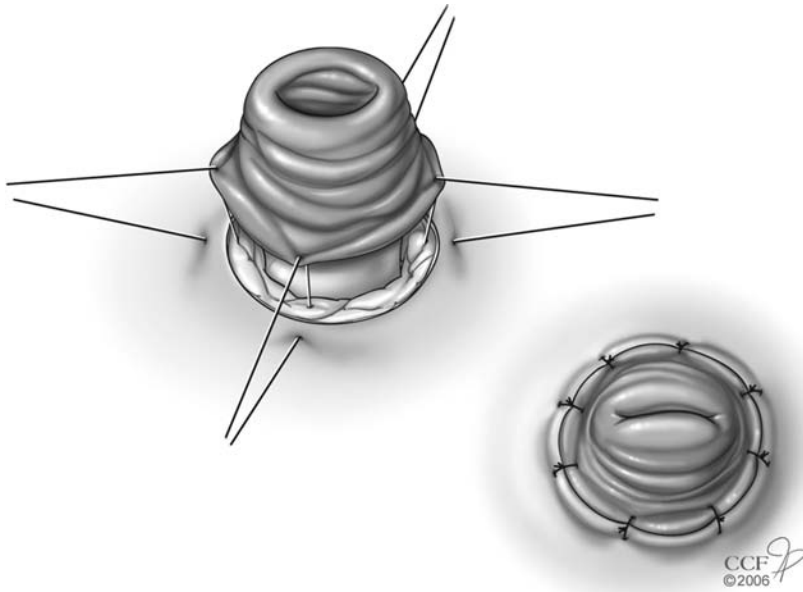


Figure 43.2 The end-loop stoma is brought up 3 cm above the skin surface and sutured in an everting fashion in four quadrants. This is followed by supporting dermal sutures. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

suture. Care should be taken during this part of the procedure to avoid ligation of the ileal blood supply. To re-establish bowel continuity, a small opening is made in the antimesenteric ends of the stapled bowel. Using a GIA stapler, the antimesenteric sides of the two ends are brought together and stapled, forming a wide anastomosis. The proximal end of the staple line is secured using interrupted 3-0 silk suture. Using a TA55 bowel stapler, the proximal end of the open anastomosis is closed. The staple line is oversewn with a 3-0 silk running Lembert suture. Exclusion of the conduit and restoration of bowel continuity can also be performed without staplers, using hand-sewing techniques, according to the surgeon's preference.

Sterile towels are placed beneath the isolated ileal conduit. The staple line at the distal (efferent) end of the conduit is excised and the conduit lumen is opened. A small opening is made in the proximal end of the conduit, and the conduit is irrigated free of enteric contents with normal saline irrigation. At this point, either the ureteroenteric anastomosis or the stoma formation can be completed. We prefer to prepare the stoma site first to allow for more optimal localization of the ureteroileal anastomosis. In obese patients, the final maturation of the stoma can be performed after the ureteroileal anastomosis is performed, to avoid difficulty in passing the stents through a thick abdominal wall.

Stoma formation

Kocher clamps are placed at the skin edge and at the fascial and peritoneal edges to align all of the layers. A circular plug of skin is excised from the predetermined

stoma site. Dissection is carried through the subcutaneous fat to the anterior rectus fascia. A cruciate incision is made in the fascia, exposing the belly of the rectus muscle. Using a Kelly clamp, the muscle is bluntly separated to expose the posterior rectus fascia. A linear incision is made through this layer as well as through the peritoneum. Care is taken to avoid the epigastric vessels, which can be palpated simultaneously. The Kelly clamp is spread to allow for the passage of two fingers. This approximately 2 cm breadth allows for passage of the conduit without compromising the blood supply and helps to prevent parastomal hernias. At this point, the distal end of the conduit, in an isoperistaltic orientation, is brought through the stoma site with care. The authors prefer to secure the base of the conduit to the sacral promontory or to the retroperitoneal fibrous tissue after completing the ureteroileal anastomosis.

End-loop nipple stoma

In preparing the stoma after the ureteroileal anastomosis, care should be taken not to apply tension to the anastomotic sites. In the standard end-loop nipple stoma, the distal end of the conduit is brought through the previously prepared stoma opening using Babcock clamps to approximately 3 cm above the skin surface. The 'rosebud' is formed using four quadrant sutures of 3-0 chromic that go through the dermis edge, catch the serosa of the conduit well below the skin level, and go through the full-thickness edge of the conduit. This suture will evert the stoma. Additional 3-0 chromic sutures are placed between the quadrant sutures to secure the conduit to the dermis (Figure 43.2). A

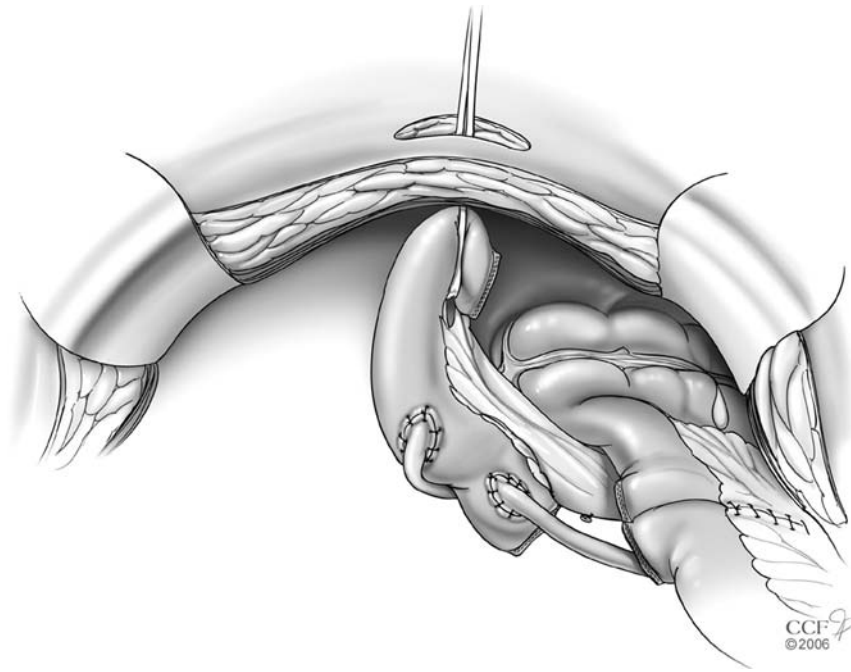


Figure 43.3 The Turnbull stoma is started by bringing up the distal loop of conduit by placing umbilical tape through the mesentery 3 cm from the distal end. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

securing suture of 2-0 Vicryl may be placed to secure the conduit to the inside of the abdominal wall. The proximal end and ureteric anastomosis may also be covered with the posterior peritoneum to minimize leakage of urine and promote healing.

Turnbull stoma

A Turnbull stoma may be used in obese patients with a short mesentery.⁴ The distal (efferent) end of the conduit remains stapled closed. A small mesenteric opening should be made adjacent to the bowel approximately 3 cm from the distal end. Umbilical tape is placed through the opening and the antimesenteric side of the loop is brought out through the stoma opening at least 2–3 cm without tension or twisting the conduit (Figure 43.3). The blind end of the loop should be positioned cephalad. A plastic rod replaces the Penrose drain and is secured in position. The loop is opened transversely and is matured in the same everting manner as the end-loop stoma (Figures 43.4 and 43.5).

The Turnbull stoma is advantageous to use over the end-loop nipple stoma when there is a short, bulky mesentery commonly seen in obese patients, combined with a thick abdominal wall, because it has a decreased tendency for retraction and stenosis. However, parastomal hernias are more commonly associated with the Turnbull stoma. The end-loop nipple stoma provides for excellent appliance placement and less skin irritation, however, stomal stenosis is more common with the end-loop nipple stoma.

Ureteroileal anastomosis

The principles to consider during creation of the ureteroileal anastomosis include maintenance of adequate distal ureteral blood supply, the maintenance of a tension-free anastomosis, absence of malignancy in the distal ureter (in cancer cases), and the avoidance of ureteral kinking or twisting. If the stoma site is located on the right lower quadrant of the abdomen, the left ureter is passed under or through the sigmoid mesocolon to the right side. The hole in the sigmoid mesentery is usually made at the level of the sacral promontory; however, it may be more cephalad depending on the length of ureter and to avoid kinking the ureter. Employing the Bricker technique, the ureters are positioned to a site on the conduit where the ureter has a natural lie. The ureter is then spatulated. An interrupted 4-0 Vicryl stay suture is placed through the adventitia of the ureter and the serosa of the ileal conduit proximal to the ureteral spatulation and the anastomotic site. The stay suture prevents inadvertent tension on the ureteroileal anastomosis during the suturing process. The site on the conduit is then incised down through the mucosa and an opening is made wide enough to accommodate the anastomosis. A full-thickness anastomosis is completed using 4-0 or 5-0 Vicryl in interrupted or continuous fashion. Technical considerations during the ureteral anastomosis include the placement of the sutures, which should include a small amount of mucosal edge and then incorporate a larger bite of muscularis and serosa. This technique will telescope the anastomosis into the ileum and

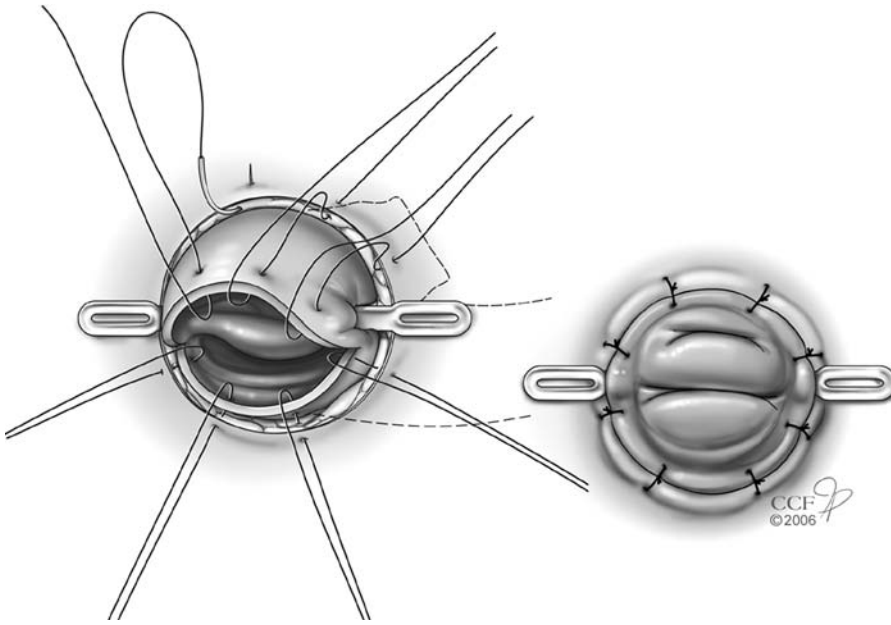


Figure 43.4 A plastic supporting rod replaces the umbilical tape. An enterotomy is made transversely and the stoma is matured in an everting fashion. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

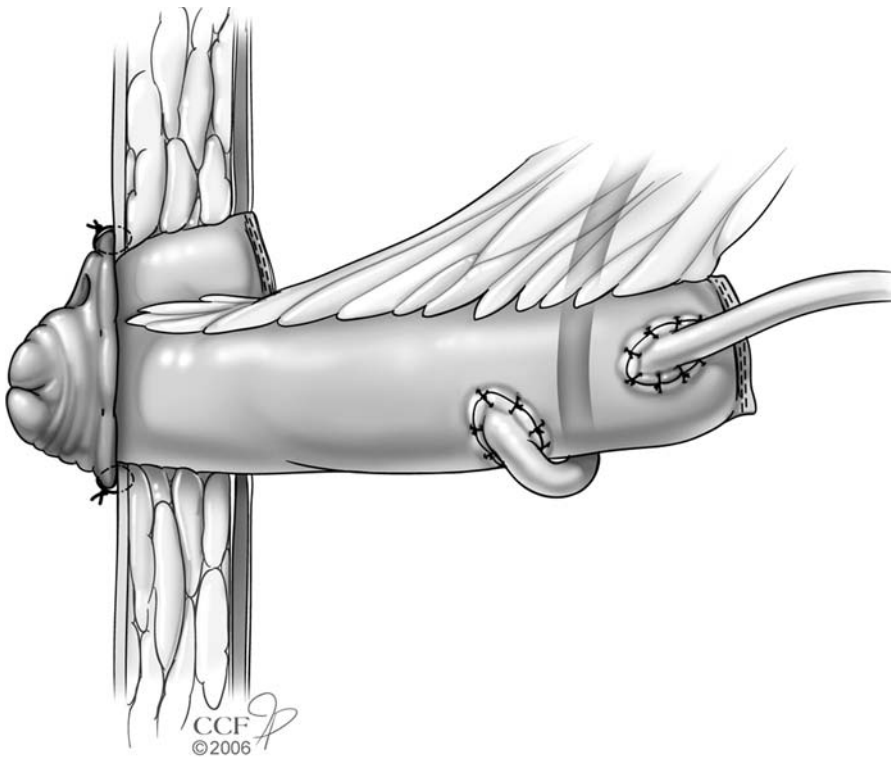


Figure 43.5 The conduit is secured to the abdominal wall. The ureters are placed at the proximal end of the conduit. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

relieve the mucosa of tension. The last three to four sutures can be placed without tying for better visualization. Prior to completion of the anastomosis, a silicone ureteral stent is placed over a wire. A suction tip or instrument (such as a long tonsil clamp) may be used to guide the stent, or it can be passed freely down the conduit to the anastomotic site. The stents are secured using 4-0 sutures to the skin at the distal end of the conduit.

The Wallace ureteroileal anastomosis involves leaving the proximal end of the ileal conduit open. The ureters are spatulated enough to accommodate the ileal conduit opening. The inside edges of the ureters are then conjoined in a side-by-side or end-to-end fashion using running 4-0 Vicryl suture. The outside edges are then anastomosed to the edges of the conduit opening with full-thickness interrupted or continuous 4-0 Vicryl suture. Prior to

completion of the anastomosis, silicone ureteral stents are placed.

An additional technique published by the Lahey Clinic⁵ includes placing the left ureter in spatulated fashion at the proximal open end of the conduit (Wallace style) and anastomosing the spatulated right ureter in an end-to-side fashion (Bricker style). This combined technique can allow for better localization of both ureters during follow-up.

Complications

The early mortality rates from prior studies range from 0.3 to 13% for patients undergoing ileal conduit urinary diversion for various reasons. Contemporary studies have demonstrated that the early major and minor postoperative complication rates are comparable in ileal conduit and continent diversions.⁶ It has been reported that the overall incidence of late complications increases each year after ileal conduit urinary diversion.⁷

Early complications occurring within the first 30–60 days postoperatively include general complications that occur after laparotomy. In a recent collaborative study, ileus was the most common early postoperative complication at 17.8%, followed by wound infection at 2.9%. Preoperative American Association of Anesthetists (ASA) score is a negative prognostic factor for major early postoperative complications, as well as for transfusion requirement and intensive care unit monitoring.

Early stomal complications are rare and can include ischemic necrosis and significant bleeding. Necrosis of the stoma site requires operative revision. Bleeding can usually be managed at the bedside with gentle pressure or placement of a stitch. Late stomal complications include dermatitis, stomal stenosis, parastomal hernia, stomal prolapse, or retraction. Stomal stenosis occurs in 3–6% of patients following ileal conduit diversion. Most cases of stomal stenosis require surgical revision. Parastomal hernias can occur in 10–15% of patients in the long term and usually require reduction of the hernia with repair of the defect or re-positioning of the stoma.

Ureteroileal anastomotic complications can occur in the setting of urinary extravasation early postoperatively, with contemporary series reporting 0.3–1.3% incidence. Late complications may include ureteral obstruction due to stricture at the ureteroileal anastomosis. Percutaneous management includes nephrostomy tubes with nephrostograms and possible antegrade stenting. The retrograde approach with stenting is an alternative approach, but

may be more technically challenging. Late and dense strictures usually do not respond to interventional treatment, and require open surgical repair.

Metabolic complications occur in all intestinal urinary diversions.⁸ Patients with ileal conduits are less likely to have serious metabolic derangements as a result of having a less absorptive surface and minimal contact time with the urine. Hyperchloremic hypokalemic metabolic acidosis is the most common metabolic complication for the ileal conduit. The mechanism of this is increased ammonium absorption via the sodium receptors in addition to absorption of chloride in exchange for bicarbonate. Treatment of the metabolic acidosis lies in direct alkalinization. Oral potassium citrate therapy is effective and well tolerated.

Renal deterioration may occur long term following ileal conduit urinary diversion. The etiology of this phenomenon is unknown as it can occur in the absence of obstruction and infections. Over the long term 8.1% of patients can develop severe renal insufficiency with ileal conduit.

Nephrolithiasis is a late complication of ileal conduit with increasing incidence at longer follow-up. The stones are usually located in the kidneys. Risk factors for stone formation include infection, hyperchloremic acidosis, and high conduit residual volumes. Struvite is the most common type of stone found in this cohort of patients.

Urinary tract infection is a common complication following urinary diversion and can occur either early or late in the postoperative course, and ranges from asymptomatic bacteriuria to pyelonephritis and eventually to urosepsis. All clinically significant infections should prompt evaluation of the urinary diversion anatomy to rule out obstruction from stomal stenosis or ureteroenteric stricture.

ILEOCECAL CONDUIT

The ileocecal antirefluxing conduit was first employed in 1969 and its use first reported in 1975. It was initially used by Gilchrist et al⁹ for developing a continent neobladder. The segment of bowel was subsequently used for augmentation cystoplasty; however, its use as a non-refluxing conduit was first described by Libertino and Zinman in 1975.¹⁰ Lower rates of stomal stenosis in colonic conduits and the ability to use the ileocecal valve as a non-refluxing functional conduit led to its use and development. The Nissen fundoplication technique, adapted by Libertino and Zinman for the ileocecal junction, transforms the

ileocecal valve into a non-obstructing antirefluxing valve. In combination with an abundant blood supply and the advantages of a colonic stoma, the ileocecal conduit is a viable form of conduit urinary diversion.

Operative technique

A midline incision extending from the pubic symphysis to above the umbilicus is made to ensure adequate exposure. The extirpative procedure and mobilization of the ureters is completed initially. The lateral and hepatic attachments of the right colon are taken down to mobilize the cecum and ascending colon. The mesentery of the right colon is transilluminated and the ileocolic artery and its branches are identified. Two 3-0 stay sutures are placed in the terminal ileum approximately 10 cm from the ileocecal valve and at 10–15 cm distal to the valve just proximal to the right colic artery. The crossing vessels in the mesentery of the ileocolic pedicle are clamped and ligated to isolate a broad pedicle for the ileocecal conduit. The bowel is then divided sharply or with GIA staplers. The isolated conduit is placed caudal to the mesentery. Bowel continuity is achieved using an end-to-end or side-to-end ileocecal anastomosis with staplers or suture.

Following isolation of the ileocecal valve, both ends of the isolated segment are opened and irrigated free of bowel contents. A 30 Fr catheter is placed through the segment to facilitate the plication and to prevent an excessively tight plication. The ileum is intussuscepted into the cecum with non-absorbable 3-0 suture. The suture is placed through the serosa of the ileum and then through the serosa of the cecum. The redundant cecum is then wrapped around the ileum fully and secured using seromuscular 3-0 suture in interrupted fashion. Care is taken to avoid obtaining mucosa in the seromuscular reinforcement suture to prevent stone formation. The ureters are anastomosed to the ileum using either the Wallace or Bricker anastomosis (see section in Ileal conduit section).

The cecal end of the conduit is brought through the created stoma in the right lower quadrant at the previously marked site using an everting nipple-style stoma.

JEJUNAL CONDUIT

Indications

The use of jejunum is advantageous in cases of extensive pelvic radiation or inflammatory disease precluding the

use of ileum. However, due to its physiologic consequences, its use is not recommended when there are other available alternatives.

Operative technique

The procedure is similar to the operative technique described for the ileal conduit (see above). The jejunum is harvested approximately 20 cm from the ligament of Treitz. The shortest possible length of jejunum should be harvested to minimize the contact time the conduit will have with the urine. The most favorable stoma position usually becomes the left upper quadrant.

Complications

Surgical complications for the jejunal conduit are similar to those of the ileal conduit. However, the metabolic derangements of the jejunal conduit are more severe than the colonic or ileal conduits. Electrolyte imbalance is more common with the jejunal conduit, notably for hyponatremia, hypochloremia, hyperkalemia, azotemia, and acidosis. The jejunal conduit syndrome, which presents with nausea, emesis, anorexia, lethargy, and muscle weakness, is treated with salt and bicarbonate repletion and hydration.

SIGMOID COLONIC CONDUIT

Reports of deterioration of the upper urinary tracts in children due to the free reflux from ileal conduits led to redirecting attention to colonic conduits. The use of sigmoid colon as a urinary conduit was first reported by Gross and Mogg in 1967. The colon with its thicker musculature is more amenable to the creation of submucosal tunnels and non-refluxing ureterocolonic anastomosis, allowing for adaptation of Coffey's ureteral anastomotic techniques. The wide-caliber lumen of the colon also provides for an excellent stoma with little risk of stenosis. The sigmoid colon is usually redundant and mobile, allowing it to be a suitable urinary conduit.

Indications

Sigmoid urinary diversions can be used in the pediatric population where an anti-refluxing ureteroenteric

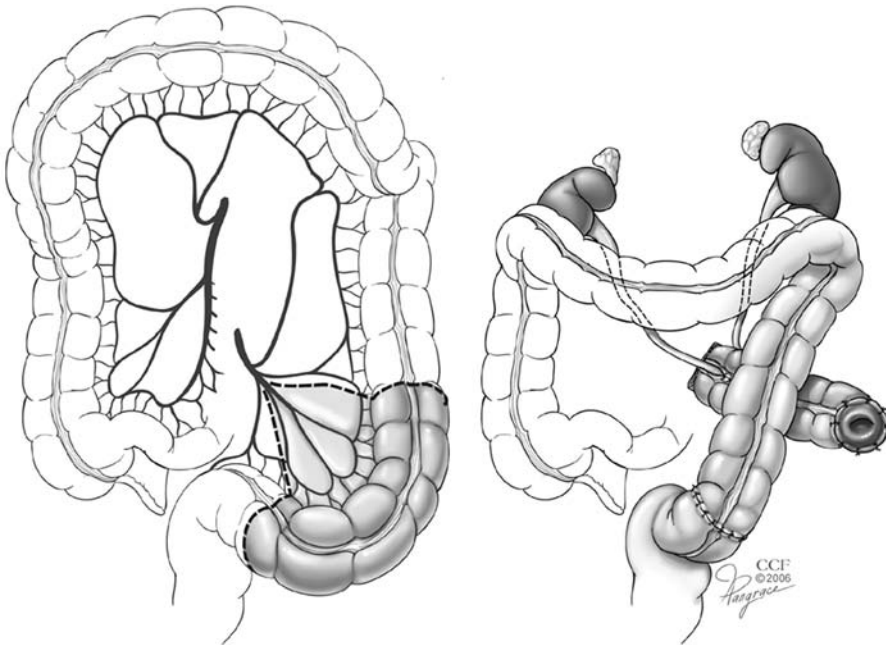


Figure 43.6 The sigmoid conduit is isolated and placed laterally to the reconstituted bowel continuity. The ureters are anastomosed in a non-refluxing manner. The stoma is placed in the left lower quadrant. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

anastomosis can reduce the potential for long-term renal scarring. Patients with Crohn's disease can be diverted using sigmoid colon. The sigmoid conduit should be avoided in patients with extensive pelvic radiation therapy. If the hypogastric arteries will be ligated during cystectomy, use of the sigmoid as a conduit might compromise the blood supply of the rectum. In contrast, the sigmoid colon is an ideal conduit following total pelvic exenteration as it eliminates the need for an intestinal anastomosis.

Preoperative preparation

Preoperative preparation is similar to the preoperative preparation for the ileal conduit (see above). Use of a colonic enema is recommended on the night prior to surgery.

Operative technique

The patient is positioned supine with the table flexed approximately 10°. The blood supply to the sigmoid colon from the inferior mesenteric artery is identified.

The sigmoid colon is mobilized from its lateral and posterior attachments. A 15–20 cm segment of sigmoid colon is chosen for the conduit. Stay sutures are placed at the proximal and distal ends of the segment to be harvested. A broad-based mesenteric blood supply is isolated for the sigmoid conduit. Division of the

proximal mesentery is shorter than the distal mesentery to ensure adequate arterial blood supply to the isolated segment. The isolated sigmoid segment is placed lateral to the sigmoid colon. The sigmoid colon is anastomosed using a two-layer end-to-end anastomosis and the mesenteric trap is closed. The isolated segment is irrigated free of colonic contents. The proximal end of the conduit is closed in two layers. The sigmoid conduit is then rotated 180° clockwise such that the proximal end is placed close to the previously dissected ureters (Figure 43.6).

Stoma formation

The stoma is created at the predetermined site, in the same manner as an ileal conduit. The sigmoid conduit is brought through the stoma site approximately 3–4 cm. The stoma is created using the end-loop nipple stoma technique (see Ileal conduits section). It is important to create a stoma that adequately protrudes from the skin edge.

Ureterocolonic anastomosis

The right ureter is brought through the sigmoid mesocolon to the left side. An incision is made using a No.15 blade in the tenia libera. Dissection is carried through the muscularis to expose the mucosa. The submucosal layer is dissected approximately 1 cm on either side of

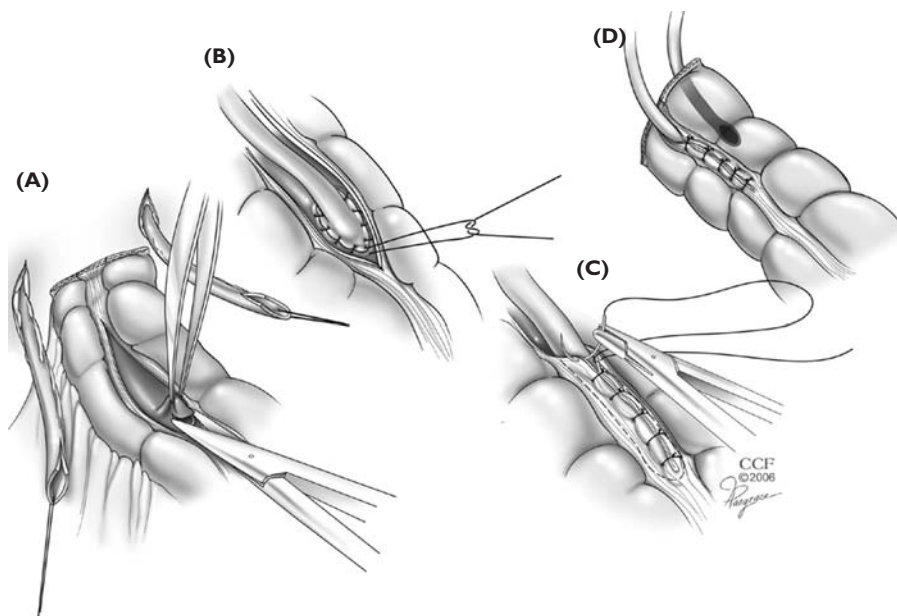


Figure 43.7 The ureterocolonic anastomosis is placed along the tenia libera in a tunneled, antirefluxing fashion. (A) The tenia is dissected free from the mucosa and flaps are formed. (B) The mucosa is incised and anastomosed to the ureter. (C) and (D) The tenia is closed loosely over the ureter completing the tunneled anastomosis. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

the muscularis to create seromuscular flaps. The mucosa is incised for an approximately 3 mm opening. The ureter is spatulated and a stay suture is placed proximally attaching the ureter to the seromuscularis layer to minimize handling of the ureter during the anastomosis. An interrupted or running mucosal-to-mucosal anastomosis is completed. Prior to completion of the anastomosis, a ureteral stent is placed. The seromuscularis layer is closed loosely over the ureteral anastomosis in interrupted fashion (Figure 43.7). The closure should allow a right angle clamp to be passed easily into the tunnel.

Complications

See section on complications in the Transverse colonic conduit section.

TRANSVERSE COLONIC CONDUIT

Indications

The transverse colonic conduit can be used in any patient requiring urinary diversion. It is ideal in children and adults who have received pelvic radiation; situations where the ileum and sigmoid colon are precluded from use. Patients with a history of recurrent retroperitoneal fibrosis, Crohn's disease, and unsuccessful primary urinary diversion (where the ureters are significantly shortened) can be managed with a transverse colonic urinary conduit. It offers non-refluxing ureteric anastomoses as well as the ability to position the stoma in the left or right upper quadrant.

Contraindications for the transverse colonic conduit include ulcerative colitis, irradiation of the upper abdomen, and history of extensive colon resection.

Preoperative preparation

The preoperative preparation is the same as for the sigmoid colonic conduit (see Sigmoid colonic conduit section).

Operative technique

The patient is placed in the supine position and access is gained through a midline incision extending from above the umbilicus to the pubic symphysis. The ureters are mobilized in standard fashion. The ureters are inspected for areas of devascularization and irradiation damage. The remaining healthy ureters are brought through the retroperitoneum via mesenteric openings that are made bilaterally. These openings should be wide enough to accommodate the ureters and to avoid kinking or compression of the ureters.

When selecting the transverse colon as the segment of conduit urinary diversion, the right colon and left colon must be mobilized to provide a tension-free colocolostomy. A segment of transverse colon is selected approximately 15–20 cm in length. Stay sutures are placed on the proximal and distal ends of the segment. The entire greater omentum is separated from the transverse colon. The mesentery is inspected and blood supply to the selected segment of conduit is identified. The mesenteric arcade of vessels is clamped and ligated.

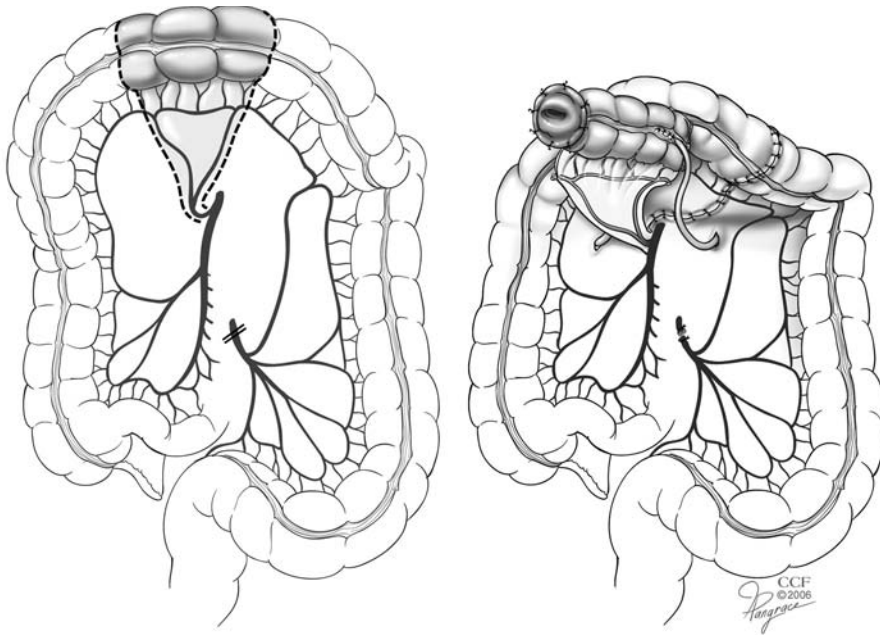


Figure 43.8 The isolated segment of transverse colon placed anterior to the colonic anastomosis. The ureters are brought out of the retroperitoneum through mesenteric windows. The stoma should be oriented in an isoperistaltic orientation. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

The selected colonic segment is divided proximally and distally with either a stapler or sharp division. Bowel continuity is established with either a stapled or hand-sewn end-to-end colocolostomy. The mesenteric trap is closed in interrupted fashion. The segment is irrigated free of colonic contents. Depending on the type of ureterocolonic anastomosis, the proximal end of the transverse colonic conduit may be closed or left open (when using the Wallace technique).

Ureterocolonic anastomosis

Principles to remember during the ureterocolonic anastomosis include maintenance of adequate distal ureteral blood supply, the maintenance of a tension-free anastomosis, documented malignancy free distal ureter (in cancer cases), and the avoidance of ureteral kinking or twisting. The ureters should preferably be anastomosed to the proximal end of the conduit. In cases where the ureters are completely destroyed and unviable for anastomosis, the conduit can be connected directly to the renal pelvis in either an end-to-end or end-to-side fashion (pyelotransverse pyelocutaneostomy). The ureterocolonic anastomosis can be completed with either the Wallace technique or a tunneled anastomosis (Figure 43.8).

Stoma formation

The stoma for the transverse colonic conduit can be placed in either the right or left upper quadrant. The procedure for the formation of the conduit is technically similar to the sigmoid conduit stoma formation.

Complications

As a result of the upper tract complications reported in children with ileal conduits, the colonic conduit was explored owing to its viability as a non-refluxing conduit. Certain series on colonic conduit reported early complication rates of up to 4.8% in the pediatric population (age less than 20). A majority of the complications were related to postoperative ileus.

Late complications include stomal stenosis rates of 15.5%, and pyelonephritis rates of 7.6%. Renal calculi are reported to develop in 8.2% of renal units involved in urinary diversion. Ureterocolonic stenosis occurred in 6.9% of patients postoperatively after a mean of 5.8 months.⁹

Dilatation and pyelonephritic changes in the upper tracts were tracked in 155 renal units in one study. In 77 renal units with no preoperative dilatation, two had mild/moderate postoperative dilatation and two required nephrectomy for non-functioning status.

Metabolic complications include hyperchloremic acidosis, a well known complication in patients with continent uretersigmoidostomies. However, in a contemporary series involving pediatric patients with minimum 5-year follow-up, less than 1% of patients were reported to have acidosis. With stringent monitoring of acid-base level osteomalacia can be avoided in patients in the long term. Secondary malignancy in continent uretersigmoidostomy is reported to be as high as 40% in patients observed long term, with an average latency period of 26 years. However, cases of adenocarcinoma in the non-continent colonic conduit are extremely rare, with many long-term studies reporting no incidences of secondary malignancy.

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44 Continent cutaneous diversion: ileum

Hassan Abol-Enein and Mohamed A Ghoneim

INTRODUCTION

A substantial number of techniques have been described for creation of continent cutaneous urinary reservoirs. For construction of such systems three elements are required: a low pressure compliant reservoir, an antirefluxive ureterointestinal anastomosis, and a continent stoma which allows easy catheterization.

To create a reservoir with high capacity at low pressure, various segments of bowel have been utilized including the ileum,¹ ileocolonic region,² the ascending colon,³ and transverse colon.⁴ Regardless of the selected bowel segment, detubularization and double folding are basic prerequisites to achieve this goal.

A reliable antirefluxive ureterointestinal anastomosis is necessary, since bacteriuria is a constant feature in these systems resulting from intermittent catheterization. The technique employed should provide a unidirectional but non-obstructed flow. The anti-refluxing mechanism should not be at the expense of a higher incidence of obstructive complications.

Hinman classified continent outlets into four categories according to their mechanism of action.⁵ These included an antiperistaltic ileal segment;⁶ imbricated or tapered ileal segments resulting in passive tubular resistance;⁷ outlets using the pressure equilibration principle, including an ileal spout valve,⁸ flutter valve,⁹ inkwell hydraulic valve, intussusception nipple,¹⁰ or ileal servomechanism sphincter,¹¹ and flap valves which are created by the incorporation of tubular structures within the wall of the reservoir such as the appendix,¹² fallopian tubes,¹³ parts of ileum,¹⁴ or tubularized cecal segments.¹⁵ A multiplicity of techniques implies that none is optimal. Many of the above techniques rely on an inert or even non-physiologic mechanism, and problems and malfunctions soon appear.

In our proposed technique, we have utilized the ileum for construction of the low pressure reservoir, and a serous-lined tunnel to provide an antirefluxive mechanism¹⁶ as well as to create a reliable continent outlet.¹⁷

INDICATIONS FOR SURGERY

Any patient who requires bladder replacement is a potential candidate for this operation. The indications

for continent cutaneous urinary diversion include the following.

- (1) Pelvic malignancies. In patients for whom cystectomy is indicated for bladder cancer or those requiring an anterior pelvic exenteration for other pelvic malignancies.
- (2) Benign indications. These include neuropathic bladders when conservative measures fail, extensive urethral strictures with damaged urethral sphincter, contracted bladders with compromised urinary continence, complex urinary fistulae affecting the sphincteric mechanism, and some cases of bladder exstrophy with failed attempts at primary repair.
- (3) Urinary conversion. From other types of urinary diversion such as ileal conduits in young healthy patients, patients who develop isolated urethral recurrence following radical cystectomy and orthotopic bladder substitution, and in some cases of ureterosigmoidostomy suffering from intractable metabolic acidosis.

PATIENT SELECTION AND EVALUATION

Suitable candidates should have reasonable manual dexterity. Motivation to carry out clean intermittent catheterization at regular intervals is necessary. Furthermore, a good prognosis might be expected if the indication of diversion was a pelvic malignancy. Patients who are unfit for prolonged surgery and those with a history of previous bowel resection, short bowel syndrome, or heavily irradiated bowel are among those contraindicated for this procedure. Patients with impaired renal function (serum creatinine of 1.8 mg/dl or more and/or creatinine clearance 40 ml/min or less) are unsuitable candidates since metabolic acidosis would be inevitable.

ALTERNATIVE THERAPY

Alternative techniques of urinary diversion should be discussed with the patient when orthotopic bladder substitution or continent cutaneous reservoirs are

contraindicated or unfeasible. These include conduit diversion and anal sphincter controlled bladder substitutes. The potential postoperative complications, changes in the future lifestyle, and long-term sequelae should be clearly explained to patients.

SURGICAL TECHNIQUE

Preoperative preparation

Since the small bowel is utilized, no specific preparation is necessary. Only fasting over night with administration of intravenous fluids to ensure good hydration is required. Patients with a history of thromboembolic disease or varicose veins should receive a prophylactic dose of heparin (5000 U subcutaneously) the night before the operation and every 12 hours thereafter until ambulation. Compression leg stockings are also advised. Although the intention is to use a concealed umbilical stoma, a stoma therapist should examine the patient and a suitable abdominal stoma site be determined. A parenteral broad-spectrum antibiotic is given just before induction of anesthesia and continued postoperatively for 3 days.

Operative technique

The patient is put in the supine position with a Trendelenberg tilt. Slight flexion of the knees would further help in the relaxation of the abdominal muscles, facilitate retraction, and provide wider exposure. If total urethrectomy is planned, the patient is put in a slight lithotomy position for access to the perineum. The surgical area to be sterilized and draped extends from the lower chest down to the upper thighs.

A midline incision from the pubis inferiorly to a point half way between the umbilicus and xyphoid process of the sternum superiorly is generally employed. The incision should encircle the umbilicus by 2–3 cm to the left.

The bowel is examined and a 60 cm long segment of the terminal ileum is isolated. Back light transillumination of the mesenteric attachment greatly helps the identification of the arterial arcades supplying the selected segments. The bowel is divided 15–20 cm proximal to the cecum in the avascular window of Treves between the ileocolic artery and the terminal branch of superior mesenteric artery. The ileum is divided proximally in a suitable avascular plane between the superior mesenteric arcades. Continuity of the bowel is re-established by

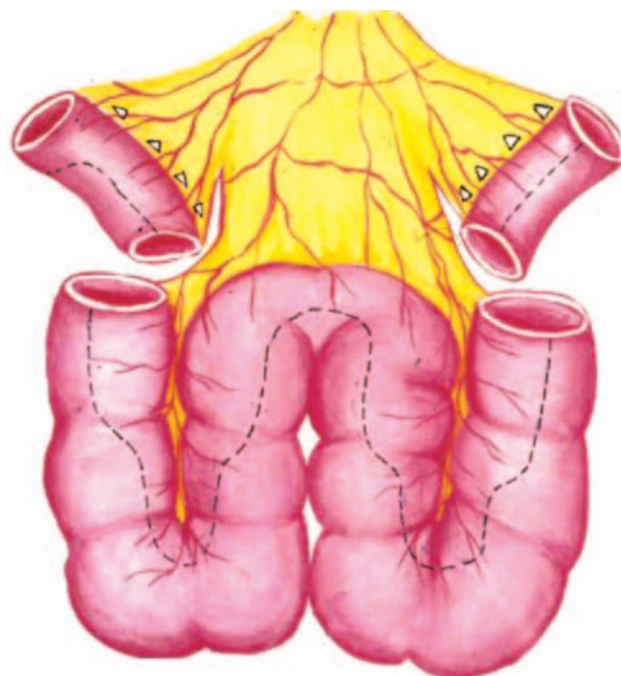


Figure 44.1 A 60 cm long ileal segment is isolated, the 40 cm middle segment is arranged in a 'W' configuration and used for construction of the body of the reservoir, the 10 cm oral segment is used for antireflux mechanism, and the caudal segment is used for the outlet valve.

end-to-end anastomosis. The use of an automatic stapler or hand-sewn technique is a matter of the surgeon's preference. The isolated bowel segment is subsequently subdivided into three parts. The middle 40 cm segment is used for construction of the reservoir, the 10 cm oral segment is used for creation of the antireflux mechanism, and the distal 10 cm caudal segment is used for creation of the outlet valve (Figure 44.1). Great attention is paid to preserve an adequate blood supply for the oral and caudal small bowel segments.

The middle segment is arranged in a 'W' configuration and its antimesenteric border is incised by a diathermy knife. The edges of the two medial flaps are joined by a single layer of continuous 3-0 polyglactin sutures. The two lateral limbs are left to serve as serous-lined troughs. The oral and caudal short segments are tapered around a 22 Fr catheter. Bowel tapering could be performed either by simple excision and hand-sewn technique, or by using a one-step technique with automatic gastrointestinal stapler. The proximal one-third of the inlet segment is kept untapered for ureteral anastomosis. Three to four small mesenteric windows close to the mesenteric border are created in between the arterial arcades supplying these segments. Each mesenteric window is marked by a small strip of rubber vessel loop. This step facilitates easy passage of sutures through the mesenteric window (Figure 44.2).

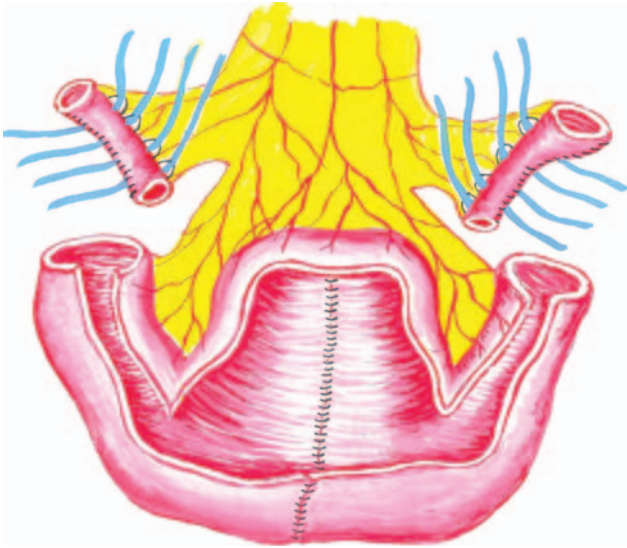


Figure 44.2 The bowel segment is incised at the antimesenteric border. The medial flaps are approximated by continuous 3-0 polyglactine sutures. The oral and caudal segments are tapered around n20 Fr catheter. The proximal one-third of the inlet segment is kept untapered. The created mesenteric windows are marked by a strips of vessel loops.

Each tapered segment is inlaid in its corresponding serous-lined trough. The two adjacent limbs of each trough are approximated using 3-0 silk seromuscular suture passing through the mesenteric windows guided by the inserted strips of vessel loops. The tapered ileal segments are fixed and embedded within the serous-lined extramural troughs. Thus, the bulky mesentery of the embedded segments is excluded behind the pouch (Figure 44.3). The spatulated distal ends of the tapered segments are anastomosed to the tunnel flaps and the ileal trough is closed in front of the embedded segment using interrupted 4-0 polyglactin suture (Figure 44.4). Two soft siliconized 8–10 Fr stents are threaded through the inlet segment and secured in place by 4-0 chromic gut sutures. The pouch plate is then closed by approximation of the most lateral ileal flaps anteriorly and to the shoulder flap between the inlet and outlet segments (Figure 44.5).

The skin of the umbilical funnel is raised and separated from the underlying rectus fascia in the midline. A fascial cruciate incision is made which can admit a 20–24 Fr catheter. The invaginated umbilical skin funnel is identified and a suitable button hole is excised. The distal end of the outlet segment is pulled through the rectus fascia aperture. The edge of the intestinal outlet is fixed to the edge of the umbilical skin funnel using interrupted monofilament 4-0 or 3-0 monocril sutures including the rectus fascia (Figure 44.6).

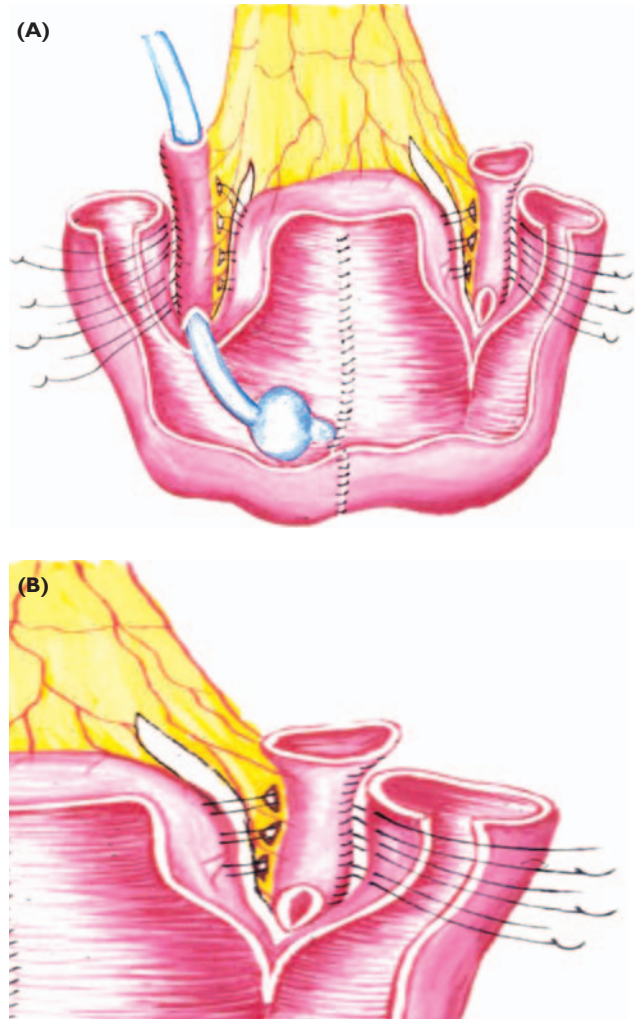


Figure 44.3 (A) The tapered ileal segments are fixed (B) Within the serous-lined extramural troughs. The ileal segments are embedded within the serous-lined troughs by passing the sutures through the mesenteric holes. Thus the bulky mesentery of the embedded segments is excluded behind the pouch.

The body of the reservoir wall around the outlet segment is then fixed to the inner aspect of the abdominal wall. Attention is paid to avoid twisting and/or angulation of the outlet segment. This avoids difficulties in catheterization later.

The reservoir is drained by outlet 18–20 Fr Foley silicone catheter fixed through the stoma.

Both ureters are prepared and oriented towards the inlet segment according to the final position of the pouch. The left ureter is passed from left to right through a high wide-enough mesenteric hole created in the left mesocolon. The right ureter comes from right to left in front of the common iliac artery behind the mesentery of the pouch. Tension-free widely spatulated stented implantation of the ureters into the inlet segment is then performed. Wallace, Nesbit, or

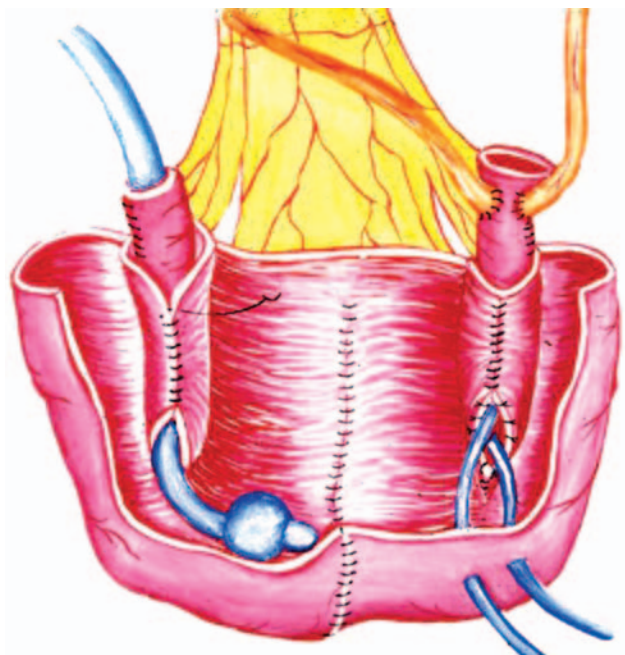


Figure 44.4 The spatulated distal ends of the tapered segments are anastomosed to the tunnel flaps and the ileal trough is closed in front of the embedded segment using interrupted 4-0 polyglactin sutures. Two siliconized stents are threaded through the inlet segment.

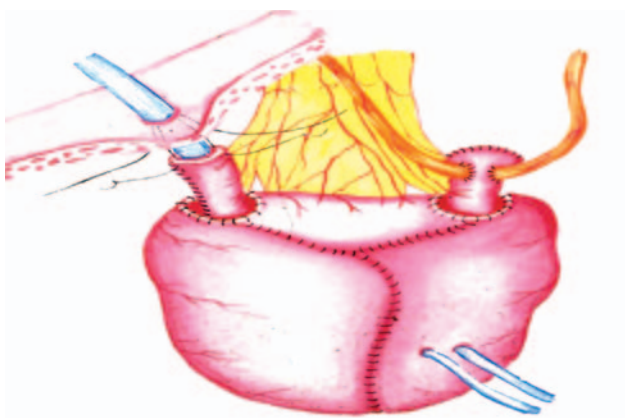


Figure 44.5 The pouch plate is closed by approximation of the most lateral ileal flaps anteriorly and to the shoulder flap between the inlet and outlet segments.

end-to-end anastomosis could be utilized according to the surgical needs using 4-0 or 5-0 polyglactin sutures.

The ureteral stents are exteriorized through the anterior wall of the reservoir to which they are secured. This provides an almost dry reservoir during the healing stage.

The pelvic cavity is drained by two 18 Fr fenestrated tubes. Straight gravity drainage only is used. Gastric drainage is established using either nasogastric tube or open gastrostomy.

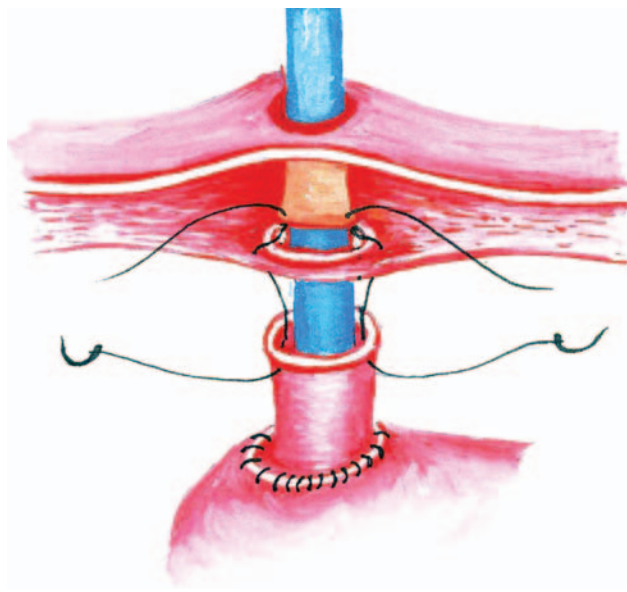


Figure 44.6 The edge of the outlet is fixed to the edge of the umbilical skin funnel using interrupted sutures including the rectus fascia.

Alternative technique: utilization of the appendix

If the appendix is suitable to serve as an outlet, the ileocecal junction is mobilized enough to ensure a tension-free implantation of the appendix. The latter is mobilized and detached at its base. The isolated appendix is cut and spatulated at its tip. The lumen is then dilated up to 16–18 Fr using straight dilators. Four windows are created in the mesoappendix. The windows are marked by rubber vessel loops. The appendix is embedded in the serous-lined trough as described previously (Figure 44.7).

Postoperative care

Parenteral fluids are maintained until bowel habit resumes. Prophylactic antibiotics are given routinely for 5 days. Low molecular weight heparin is given for 10 days. The draining tubes are removed when the drainage ceases. The reservoir is irrigated with 30–60 ml of normal saline every 8 hours to prevent mucus retention. The ureteric stents are removed after 10–12 days postoperatively. The pouch is kept drained for 21 days before training by intermittent catheter clamping. All patients start self catheterization 2 days before discharge from the hospital. A 2 hour interval is allowed in week 1, which is increased gradually until the pouch matures. By the end of week 6 most of the patients evacuate the pouch every 4–5 hours.

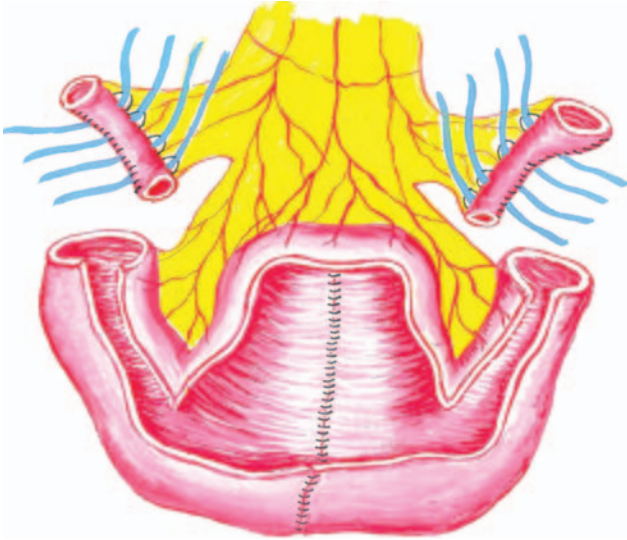


Figure 44.7 The appendix is isolated and spatulated at its tip. Four windows are created at its mesoappendix. The appendix is fixed and embedded in the serous-lined trough as described previously.

OUTCOMES

Complications

On the basis of our experience in 101 patients, early complications were observed in 15%. These included urinary leakage (2%), pelvic collections (8%), ureteroileal obstruction (1%), ileus (3%), and wound complications (3%). Small non-symptomatic pelvic collections need no treatment. Sizable and/or infected symptomatic collections are usually treated by ultrasound guided needle aspiration with or without an indwelling tube drain. None of the pelvic collections in our patients required open drainage. Urinary leakage was an infrequent complication in our series (2%). It was due to pouch perforation during catheterization training. Prolonged pouch drainage was required for an additional 2 weeks until healing of the injury occurred. Early evidence of ureteroileal obstruction was observed in one patient for which an antegrade fixation of a double-J stent was inserted for 6 weeks. The stent was removed by pouchoscopy carried out through the umbilical stoma. Gastrointestinal and wound complications were similar to other urinary diversion procedures.

Late complications included stomal stenosis at the skin level with catheterization difficulties in 6% of the patients. Two-thirds of patients had an appendix stoma. Half of these patients required revisional surgery to widen the mucocutaneous stenotic area using wedge

skin flap technique. In one child it was impossible to pass a catheter into the pouch due to over distention resulting in angulation of the outlet tract. Under ultrasound guidance, percutaneous insertion of a pig tail catheter was carried out. Once the pouch became empty, outlet catheterization again was easy. Rupture of the pouch was observed in one patient following blunt abdominal trauma. Laparotomy was necessary and the pouch tear was adequately repaired. Pouch stones were observed in 5% of the patients. All of them were amenable to endoscopic manipulations but one patient required open pouch lithotomy. The incidence of upper tract dilatation due to anastomotic stricture was minimal (1%), the stricture was treated by antegrade balloon dilatation. One patient required left nephroureterectomy 3 years following cystectomy due to a renal pelvis tumor. Gravity pouchography demonstrated reflux in three patients (3%). Reflux was asymptomatic in all and the patients were kept on prophylactic antimicrobial suppressive therapy. None of the operated patients developed metabolic acidosis. All patients were advised to use oral alkali therapy.

RESULTS

Patients regain their normal life style once healing is completed. Of our patients 95% are completely dry day and night. The catheterization interval is every 4–5 hours during day time and 1–2 hours at night. The average capacity at 6 months postoperative is 550 ± 130 ml.

Five patients (5%) had a frequently wet stoma due to failure of the continence mechanism. Two patients were revised. One underwent revision of the continent outlet, and augmentation ileo-pouchoplasty was required to increase pouch capacity in the other. Two patients preferred frequent catheterization to avoid leakage. The remaining patient used to fix a collection device during night time and refused further intervention.

Patients have to understand that they have a neobladder constructed from the bowel and this bladder is different from the native one. The usual desire to micturate and the known micturition mechanism no longer exist. However, all patients with dry continent outlet stoma enjoy an excellent lifestyle, normal social activities, accepted body image, and personal satisfaction.

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45 Continent cutaneous urinary diversion: right colonic reservoirs

Matthew N Simmons and Steven C Campbell

INTRODUCTION

Urinary diversion surgery is conducted with the primary goal of renal functional preservation. Many young and highly functional patients wish to avoid an incontinent stoma due to its negative impact on cosmesis and quality of life. Orthotopic neobladder procedures such as the Studer pouch utilize ileal bowel for their construction, and are the preferred operation for patients who wish to avoid an ileal conduit. However, orthotopic neobladder procedures require preservation of the proximal urethra and urinary sphincter, and as such are contraindicated in patients with malignant involvement of the prostatic or proximal urethra. Also, patients with pre-existing incontinence or intrinsic sphincter dysfunction would not benefit from orthotopic neobladder surgery. Continent cutaneous diversion (CCD) surgery can provide this subset of patients with a spacious and compliant reservoir that can be accessed via a continent catheterizable stoma.

Various bowel segments including ileum, stomach, colon, sigmoid, and rectum have been utilized for CCD construction. Each type of bowel reservoir carries its own set of anatomic, functional, and metabolic limitations. Right colonic reservoirs utilize the cecum, the right colon, and a 15–30 cm segment of terminal ileum. A right colonic reservoir may be chosen for patients with conditions that preclude the use of ileum for CCD construction such as dense ileal adhesions or prior small bowel resection.

PATIENT SELECTION

Patient selection for CCD is critical, as good functional outcomes are patient dependent. A thorough assessment of the physical capacity and willingness of each patient to self-catheterize must be made preoperatively. Chronic pressurization of the reservoir can lead to major issues including reservoir rupture, upper tract functional deterioration, stones, and infection. Patients with progressive neurologic disease, decreased manual dexterity, advanced age, or

mental impairment should be advised to undergo ileal conduit diversion.

Preoperative preparation for all patients should include nutritional and metabolic evaluation to confirm absence of hepatic cirrhosis, renal impairment, pre-existing colonic diseases such as short bowel syndrome, inflammatory bowel disease, or colonic malignancy. It is recommended that patients older than 50 who are considered for a right colonic CCD have a colonoscopic evaluation prior to surgery to rule out possible colonic polyposis or adenocarcinoma. Colorectal referral should be considered for all patients with risk factors for colon cancer including personal or family history of polyposis or adenocarcinoma, or a history of inflammatory bowel disease. Renal functional evaluation, including serum creatinine, computed tomography (CT) imaging, and a technetium-99m mercaptoacetyl triglycine (^{99m}Tc -MAG-3) renal scan, should be conducted to determine the baseline functional status of the kidneys. Patients with renal insufficiency (defined as serum creatinine ≥ 1.8 mg/dl or glomerular filtration rate (GFR) ≤ 60 ml/min) should be diverted via ileal conduit. All continent diversions can result in systemic absorption of urinary electrolytes and metabolic acidosis. Patients with renal impairment should not be considered for CCD, as these patients are unable to compensate for the increases in acidotic load associated with diversion.

SURGICAL PREPARATION

A thorough full bowel prep should be performed, especially since these procedures involve colonic segments. A typical antibiotic regimen consists of metronidazole combined with a cephalosporin initiated prior to surgery, and continued postoperatively for 2–3 days.

Cosmesis and accessibility of the stoma are key considerations. The stoma is typically placed at the umbilicus, but can be constructed at lateral locations based on habitus constraints or patient preference. Preoperative enterostomal consultation for stoma site marking and patient counseling is helpful.

GENERAL TECHNICAL CONSIDERATIONS

There are numerous renditions of right colonic reservoir formation in the literature; however, all are variations on three major pouch types: the Indiana pouch, the Penn pouch, and the Mainz pouch I. A midline incision extending from the umbilicus to the pubic symphysis allows for adequate exposure in most cases; however, superior extension of the midline incision is frequently required to completely mobilize the right colon.

Numerous technical considerations are common to all types of right colon continent reservoirs. Technique relating to fashioning of the ureteral anastomoses can impact stricture and reflux rates. When mobilizing the ureters, a thick (3–4 mm) sheath of periureteral tissue should be preserved to maintain the blood supply. Also, it should be ensured that the ureter is mobilized sufficiently to allow for a tension-free anastomosis, and that it is not twisted along its course to the pouch to avoid ischemia caused by torsion. Typically the left ureter is passed through a mesenteric window to allow for adequate reach. Ureters should be generously spatulated for 1–2 cm. To construct the anastomosis six to ten interrupted 4-0 or 5-0 Vicryl or chromic gut sutures should be used. By using interrupted sutures, no circumferential limit is placed on ureteral dilatation. Also, there will be less suture material present in the anastomosis to induce fibrosis. Ureteral stenting is mandatory unless the anastomosis is widely patent (i.e. >1 cm). Ureteral stents can be externalized either through the stomal conduit or they can penetrate the pouch and be brought out through the abdominal wall. Each stent should be sutured to the pouch mucosa with a single chromic gut suture adjacent to the anastomosis to prevent migration out of the ureters. A second anchor stitch should be placed at the stomal orifice.

For non-refluxing anastomoses, each ureter must be passed through a submucosal tunnel. The length of the tunnel should be based on ureteral diameter using a 4:1 tunnel length:ureteral diameter ratio. In general the non-refluxing technique has fallen out of favor due to increased stricture rates.¹ Also, reflux in adults appears to have no detrimental effect on renal function.

The stomal conduit is composed of either ileum or appendix in all types of right colonic CCDs. Construction of the continent valve mechanism is central to the success of the CCD operation. The most crucial point of outflow resistance is either the appendicocolic junction or the ileocecal valve. A second point of outflow resistance is fashioned when the conduit is passed through the belly of the rectus or through the rectus

fascia. Sequential resistance zones increase the likelihood of postoperative continence. It must be cautioned that excessive resistance to outflow can limit ease of catheterization. Also, in the case of pouch overload, the stoma conduit should be the path of least resistance to flow. In this manner the stoma conduit acts as a 'pop-off' high pressure outflow tract and prevents pouch rupture.

Care should be taken during construction of the cutaneous stoma to minimize the risk of stomal stenosis. All attempts should be made to maximize the circumference of the skin and efferent limb using spatulation. Dilatation of stomal stenosis can be treated conservatively by dilatation with urethral sounds, but most cases ultimately will require surgical revision. Treatment of stenosis in ileocecal valve-based stomas requires more invasive procedures, thus use of an appendiceal stoma is currently recommended.

All efforts should be made to ensure that the pouch suture lines are watertight. Absorbable running stitches interlocked after every third stitch effectively approximate mucosal edges and prevent purse stringing of the suture line. Use of non-absorbable suture should be avoided as with all types of urinary reservoir surgery. Pouch leaks occur most predominantly at the level of converging suture lines. Filling the pouch with 200–300 ml of saline and applying gentle pressure typically reveals defects that can be sealed with targeted interrupted sutures. Another source of urine leak is at the level of the ureteral anastomoses. Tension on the anastomosis may cause disruption or delayed healing. Ureters should be sufficiently mobilized to allow for adequate length to reach the pouch, and ureters should be anchored to the pouch wall using absorbable sutures to decrease tension and to fortify the anastomosis. In some cases anastomotic leak results from ureteral devascularization with subsequent tissue necrosis. These cases typically require surgical re-exploration and revision. It is critical to visually assess ureteral perfusion and integrity prior to reimplantation.

Ease of pouch irrigation is a primary concern, as the cecal mucosa produces copious amounts of mucus that can cause retention. In all pouches, a 24–26 Fr cecostomy tube should be placed in a dependent portion of the pouch, and secured in place using an absorbable purse string suture. This large bore catheter facilitates irrigation of blood clots or mucus plugs that form in the early postoperative period. Another helpful maneuver is to suture the reservoir wall directly to the abdominal wall at the cecostomy exit site, and securely anchor the cecostomy tube to the anterior abdominal wall during the postoperative period. This will allow

the reservoir to fuse directly to the abdominal wall. In cases of urinary retention years after surgery, the pouch can be accessed percutaneously using the cecostomy site scar as the reference point of entry. A 16–18 Fr stoma Foley catheter should be placed, and serves as the primary route for pouch irrigation during the perioperative period. Inflation of the stoma catheter balloon should be conducted with caution, as inadvertent removal of the undeinflated catheter can cause disruption or damage of the conduit. Patency and ease of irrigation of all drainage tubes should be verified and their positions modified as needed prior to closure. Jackson Pratt (JP) drains should be placed to allow for detection of urine leak, and to provide recourse for prolonged drainage if the need arises.

POUCH CONSTRUCTION

Indiana pouch

Construction of the Indiana pouch begins with isolation of 30 cm of right colon and 10 cm of terminal ileum (Figure 45.1).² The colon is mobilized to the level of the mid-transverse colon. The reservoir bowel segment is perfused by the right colic and ileocolic arteries. The colonic segment is spatulated down its anterior aspect. Both the ileal portions and the ileocecal valve are preserved to be used for stomal conduit construction. Tapering of the ileum provides a small-diameter efferent limb. This is fashioned by placing a 12 Fr catheter into the ileal lumen. Babcock clamps are placed on the antimesenteric side of the ileum to narrow the lumen to the width of the catheter. A linear stapler is then used to staple the ileum above the catheter, and is preferred over hand-sewn immobilization as the latter can lead to formation of out-pouchings that impede catheterization. Plication sutures placed at the ileocecal valve increase outflow resistance, and serve as the basis for continence. The reservoir is made by flipping the cephalad colonic border inferiorly to the spatulated edge on a horizontal axis. The cecal edges are approximated transversely using running full-thickness absorbable sutures. Once closure is halfway completed, the pouch should be situated in the abdomen in its anticipated final resting position. The mobilized ureters can then be implanted into the posterolateral pouch wall.

A 1 cm ellipse of epidermis is excised at the stoma exit site, and a tunnel is made through the subcutaneous tissues extending into the peritoneal cavity. The ileal efferent limb is delivered through the tunnel, and a cutaneous stoma is constructed.

The Indiana pouch has a reported complication rate of 28%.³ Pouch leakage was observed in 4%, stomal hernia in 4%, pouch stone formation in 4%, and pyelonephritis in 5% of cases. Continence after 1 year approaches 98%. Modifications to the Indiana pouch include the Lundiana pouch,⁴ the Florida pouch,⁵ and the University of Miami pouch.⁶ These variations differ in the amounts of bowel resected for reservoir construction, and also in the method for buttressing the ileocecal valve. A major advantage of the Indiana pouch operation is that it is less technically complex than the Penn or Mainz pouch I types. The Indiana pouch reservoir has large capacity (average 400–500 ml), low filling pressures, and is associated with a high and permanent continence rate.

Penn pouch

Construction of the Penn pouch begins with isolation of 30 cm of right colon and 20 cm of terminal ileum (Figure 45.2).^{7–9} The right colon is mobilized to the level of the mid-transverse colon. Vascular supply to the bowel segment is provided by the right colic and ileocolic arteries. The colonic and ileal segments are then spatulated along their entire antimesenteric border, extending across the ileocecal valve.

Pouch construction involves fashioning an ileal patch to cover the anterior aspect of the spatulated cecum. First, the spatulated ileal segment is evenly folded into a 'U' shape, and apposed edges are approximated using a running 3-0 Vicryl full-thickness stitch. The ileal patch is flipped anteriorly, and ileal and cecal edges are approximated. Prior to closure the pouch should be situated within the abdomen in its estimated final resting position, and the ureters should be implanted in the posterolateral wall.

The appendix is typically used for the stomal conduit in the Penn pouch. The appendix is excised from the cecum, leaving a 1–1.5 cm cecal cuff. The appendix is then rotated 180° so that its distal tip points caudally. After this maneuver arterial flow through the appendiceal mesentery must be confirmed prior to construction of the appendicostomy. The distal tip of the appendix is trimmed to accommodate an 8 Fr catheter, and is spatulated for 0.5–1 cm. A 2 cm incision is made in the cecal mucosa, and the spatulated distal appendiceal tip is anastomosed to the cecal mucosa. An accessible anteriorly located tenia is incised along its midline for 6–8 cm, and muscularis flaps are raised to accommodate the catheterized appendix, and are closed over the appendix. The proximal end of the

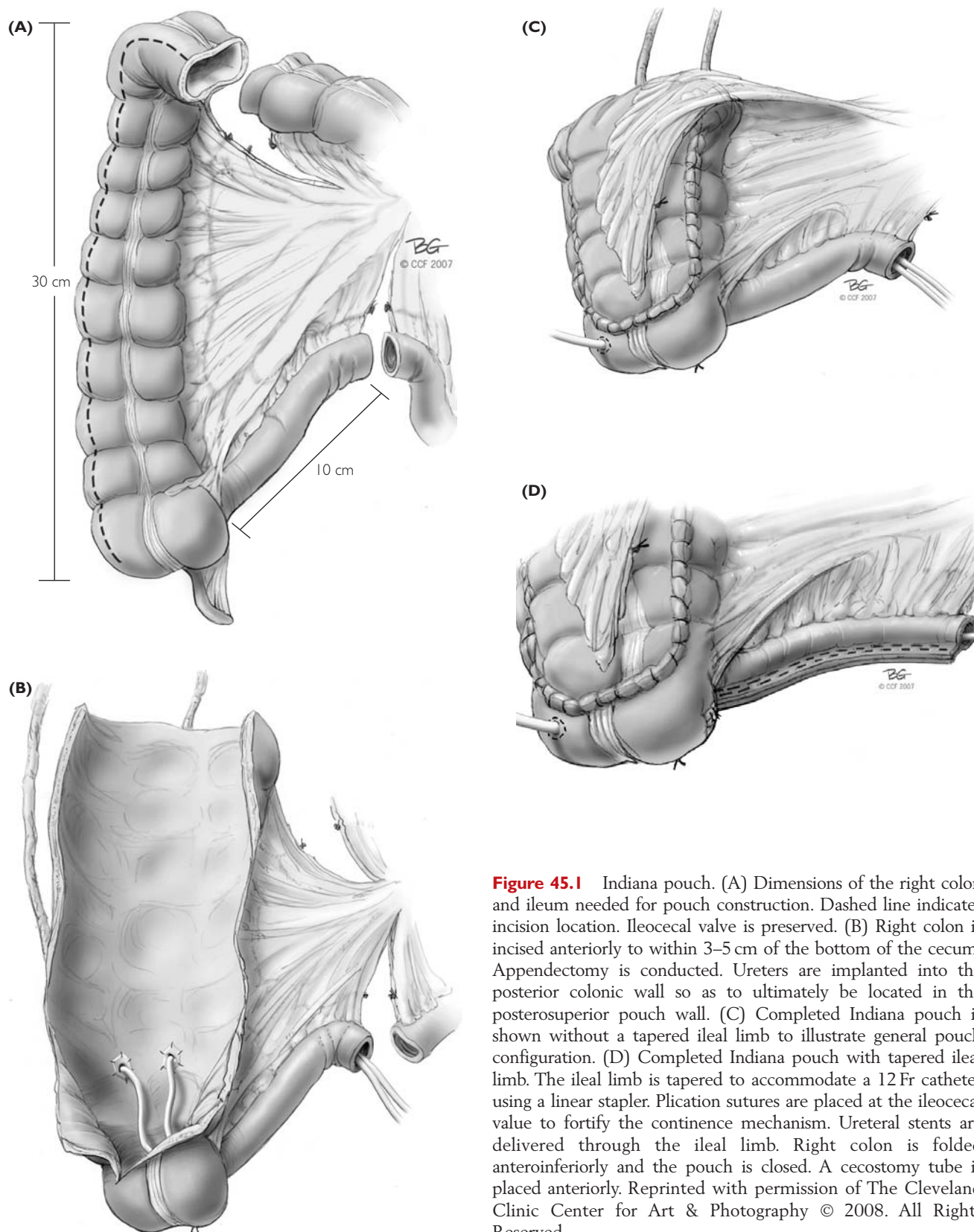


Figure 45.1 Indiana pouch. (A) Dimensions of the right colon and ileum needed for pouch construction. Dashed line indicates incision location. Ileocecal valve is preserved. (B) Right colon is incised anteriorly to within 3–5 cm of the bottom of the cecum. Appendectomy is conducted. Ureters are implanted into the posterior colonic wall so as to ultimately be located in the posterosuperior pouch wall. (C) Completed Indiana pouch is shown without a tapered ileal limb to illustrate general pouch configuration. (D) Completed Indiana pouch with tapered ileal limb. The ileal limb is tapered to accommodate a 12 Fr catheter using a linear stapler. Plication sutures are placed at the ileocecal valve to fortify the continence mechanism. Ureteral stents are delivered through the ileal limb. Right colon is folded anteroinferiorly and the pouch is closed. A cecostomy tube is placed anteriorly. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

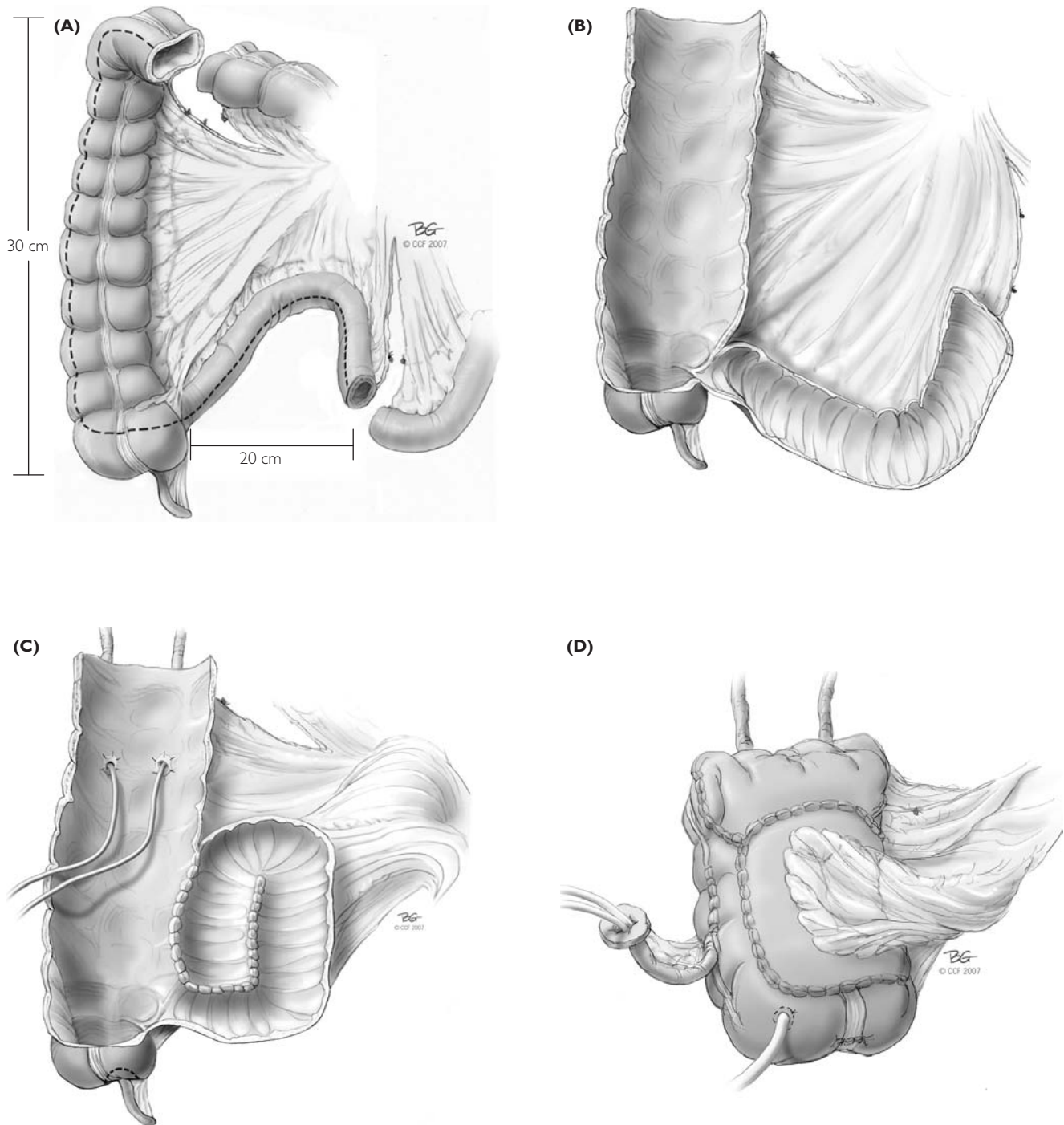


Figure 45.2 Penn pouch. (A) Dimensions of the right colon and ileum needed for pouch construction. Dashed line indicates incision location. (B) The bowel is opened across its entire length including the ileocecal valve. (C) An anterior patch is made by folding the ileum as shown and sewing the apposed edges. Ureters are implanted in the superior aspect of the pouch wall. Appendix is carefully removed to be used for appendicostomy. (D) Ileal patch is folded anteriorly, upper right colon is folded anteroinferiorly, pouch closure is conducted. Cecostomy tube is paced anteriorly. Appendix is rotated 180° on its pedicle and implanted into a lateral tenia to form the appendicostomy. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

appendix is brought through the rectus fascia at the level of the umbilicus. It is spatulated for 1–1.5 cm, and anastomosed to a subumbilical 'V' shaped skin flap to create the stomal orifice.

Modifications to the Penn pouch include use of an ileal segment for stoma construction, and construction of an ileal retroperitoneal extension to accommodate for short ureteral length. One recent variation on the Penn pouch involves a continent cutaneous ileocecal reservoir with ureteroileal coloappendicostomy (Skinner pouch).¹⁰ This pouch has an afferent terminal ileal limb, and utilizes the ileocecal valve as an antireflux mechanism. An appendiceal flap valve comprises the continence mechanism.

The Penn pouch CCD operation has a complication rate comparable with the other pouch types.¹¹ Use of the Mitrofanoff appendicostomy yielded a satisfactory continence rate as high as 96%,¹² however, stomal stenosis was observed in 19% of cases and inability to catheterize the stoma occurred in 11% of cases. Overall, the stomal revision rate for the Penn pouch stoma has been reported as high as 33%.¹¹ Advantages of the Penn pouch include the ability to construct the pouch without resection of the terminal ileum, and excellent continence rates. Disadvantages of the Penn pouch include technical complexity, and stomal stenosis complications.

Mainz pouch I

The continence mechanism of the Mainz pouch I relies upon an ileal segment intussuscepted through an intact ileocecal valve.^{13–15} Construction of the Mainz pouch begins with isolation of 15 cm of right colon, and 30 cm of terminal ileum (Figure 45.3). The colon is mobilized to the level of the hepatic flexure. The reservoir bowel segment is perfused by the right colic and ileocolic arteries. The colonic segment is spatulated along its antimesenteric border to within 1 cm of the ileocecal valve. The ileal segment is spatulated along its antimesenteric surface beginning 10 cm from the ileocecal valve and extending for 20 cm to the cut edge. During spatulation of both the cecum and ileum, care is taken to preserve the ileocecal valve. The spatulated ileum is folded evenly into a 'U' shaped configuration, and apposing edges are approximated.

Next the intussuscepted ileal nipple valve is constructed. Mesenteric fat is removed from an 8 cm portion of the unspatulated ileum starting at the ileocecal valve, taking care to preserve mesenteric blood vessels. The ileal segment is intussuscepted into the pouch, and

immobilized using a linear stapler. The stapled intussuscepted ileal loop is then pulled through the ileocecal valve and anchored using the linear stapler. A final staple line is placed from the outside of the pouch to secure the inferior aspect of the intussuscepted loop to the inferior pouch wall. The cecal and ileal components are folded together, and mucosal edges are approximated. Prior to closure, ureteral implantations should be conducted in the posterosuperior pouch wall. The conduit is then passed through the abdominal wall, and a cutaneous stoma is constructed.

Another modification of the Mainz pouch involves use of a Mitrofanoff appendicostomy rather than an ileocecal valve-based continence mechanism.^{16,17} This is an effective option if the appendix can be dilated to accommodate a 16Fr catheter. In this scenario, the lower cecum should not be spatulated. The tenia is incised at the tip of the cecum down to the level of the muscularis. The appendix mesentery adipose tissue is removed, leaving the appendiceal vessels intact. The appendix is then situated within the muscularis incisional defect, and the tenia is reapproximated over the appendix. The short appendiceal limb that emerges from the pouch is then used to conduct an appendicocutaneous stoma.

Variations on the Mainz I CCD include the Duke pouch^{18,19} and the Le Bag pouch.¹⁸ In the Duke pouch the ileocecal valve nipple is fashioned using absorbable sutures. The Le Bag pouch uses a longer terminal ileal segment, and the nipple valve is stabilized using three linear staple lines. Also, the Le Bag pouch lacks a stomal conduit, and is located directly under the cutaneous stoma site. Other variations of the Mainz pouch I situate the ureters into the pouch suture line or use tubularized cecum to construct the stomal conduit.²⁰

The Mainz I CCD operation originally reported high late complication rates of up to 37% with stomal stenosis and stone formation occurring in 8% and 6.8% of cases, respectively.^{15,21} Patients with appendiceal stomas had higher continence rates (96.8–98.6%) than those with an intussuscepted ileocecal valve nipple (90%). However, appendiceal stomas had a higher rate of stenosis than ileocecal valve stomas (18% versus 12%, respectively).²² A major disadvantage of the Mainz pouch I is its high degree of technical complexity relating to continence mechanism construction.

POSTOPERATIVE CONSIDERATIONS

The postoperative management of patients who undergo right colonic CCD surgery is unique in several regards. First, generalized ileus should be anticipated,

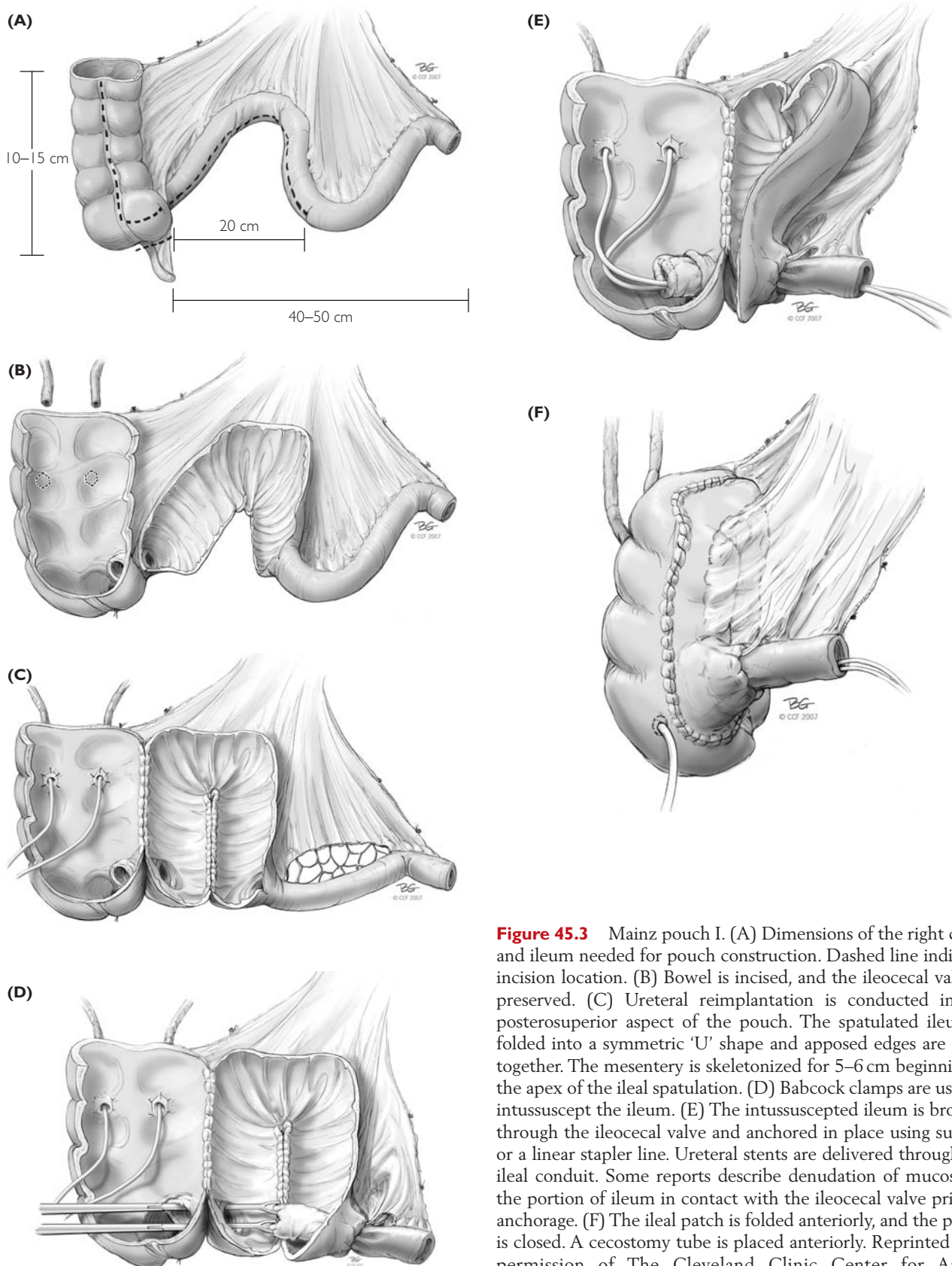


Figure 45.3 Mainz pouch I. (A) Dimensions of the right colon and ileum needed for pouch construction. Dashed line indicates incision location. (B) Bowel is incised, and the ileocecal valve is preserved. (C) Ureteral reimplantation is conducted in the posterosuperior aspect of the pouch. The spatulated ileum is folded into a symmetric 'U' shape and apposed edges are sewn together. The mesentery is skeletonized for 5–6 cm beginning at the apex of the ileal spatulation. (D) Babcock clamps are used to intussuscept the ileum. (E) The intussuscepted ileum is brought through the ileocecal valve and anchored in place using sutures or a linear stapler line. Ureteral stents are delivered through the ileal conduit. Some reports describe denudation of mucosa on the portion of ileum in contact with the ileocecal valve prior to anchorage. (F) The ileal patch is folded anteriorly, and the pouch is closed. A cecostomy tube is placed anteriorly. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

and a nasogastric tube should remain in place for 1–2 days postoperatively. Oral intake should be restricted until signs of bowel function are evident.

Another postoperative consideration in these patients is fluid and electrolyte balance. Electrolyte absorption by the cecum is especially problematic when there is inadequate drainage of the reservoir. Daily electrolyte monitoring should be conducted to evaluate for hyperchloremic acidosis. Fluid replacement should be sufficient to maintain adequate urine output, and should also compensate for fluid and electrolyte losses from the nasogastric tube.

Elevated postoperative JP drain output persistence should raise suspicion for urine leak, and measurement of elevated creatinine in the drainage fluid can confirm this complication. Early in the postoperative course, urine extravasation is usually caused by pouch pressurization due to mucus plug obstruction. Pouch irrigation should be conducted at least twice daily, and the patient should be instructed on how to self-irrigate while in the hospital so that they can effectively manage the pouch at home. The first step in managing urine leaks at any time after surgery is to depressurize the pouch using the cecostomy and stoma Foley catheters. Delayed leaks typically resolve with prolonged JP and pouch drainage.

Ureteral stents are typically removed after 7–14 days in the absence of evidence for urine leak. A pouchogram should be conducted 3–4 weeks after surgery to assess for extravasation. If there is no leakage, the cecostomy and stomal catheters can be removed, and a clean intermittent catheterization schedule can be initiated.

A possible late complication of right colonic CCD involves malabsorption of vitamin B₁₂ and folate. This is typically seen 2–3 years after surgery, especially when terminal ileum is utilized for pouch construction. Fortunately, folate deficiency and pernicious anemia have not been widely reported in these patients. Regardless, routine postoperative evaluation for malabsorption-related conditions is recommended.

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46 Urinary diversion into the rectosigmoid Mainz pouch II

Rudolf Hohenfellner

INTRODUCTION

The basic principle of the Mainz pouch II involves the construction of a continent rectal reservoir of high capacity and low pressure with antirefluxive ureteral implantation. This was mentioned first by Kocher in 1903 and clinically implemented by Fisch in 1991.¹

Indications

The Mainz pouch II is the method of choice for continent urinary diversion in patients with anatomic or functional loss of the bladder who have a competent anal sphincter. In case of ureter obstruction in ureterosigmoidostomy or to change the incontinent colon conduit in a continent form of diversion, conversion in a Mainz pouch II can be performed.

Prerequisites

A competent anal sphincter is a prerequisite for the procedure. The patient must be able to hold an enema of 350 ml of saline for a minimum of 3 hours while sleeping during night and while walking and working during the day. Rectodynamics with anal sphincter profile are optional and include resting closure pressure that should be more than 60 cmH₂O and closure pressure under stress of more than 100 cmH₂O. Good patient's compliance is mandatory, as patients require life-long antiacidotic treatment and yearly colonoscopy starting at the 5th postoperative year.

Contraindications

Contraindications include pelvic irradiation, previous bowel surgery for benign or malignant colorectal disease, diverticulosis or polyposis of the sigmoid colon, non-organ-confined bladder cancer, planned adjuvant irradiation, cerebral arteriosclerosis, diabetes, serum creatinine levels above 1.5 mg/dl, high cardiopulmonary risk (ASA 3–4), and obesity.

In patients with dilated upper urinary tract (grade 2–3) modified ureteral implantation should be undertaken. Rectal incontinence during chemotherapy is common.

PREOPERATIVE WORK-UP

A contrast enema (water soluble) is administered to exclude malignancy of the colon and diverticula, using colonoscopy or three-dimensional computed tomography. The length of sigmoid colon to be used should be estimated preoperatively. If it is short, extended mobilization of the flexura lienalis may become necessary.

Bowel preparation is performed with 4–7 liters of FORTRAN's solution on the day before surgery. Antibiotic prophylaxis with metronidazole combined with cephalosporin and aminoglycoside is administered.

Patient consent and understanding regarding the life-long control of acidosis and its early treatment, as well as relating to complications and treatment must be obtained. In the unexpected and rare case of postoperative frequency, urgency, and nocturia (in up to 3%) conversion to a continent reservoir with umbilical stoma is recommended.

General or peridural anesthesia is administered.

Fine instruments and a 2.5 × lens system are used for antirefluxive ureteral implantation.

SURGERY

A rectal tube is placed preoperatively to facilitate removal of the ureteral stents during surgery. The rectal tube – placed preoperatively – is pulled out so the stents inserted in the tube became visible and can later on be fixed. Then the rectal tube is reinserted to drain the pouch.

A midline laparotomy is performed and the length of the rectosigmoid estimated. Two stay sutures are placed at 3 and 9 o'clock (at the level of the promontory, to which the pouch will be fixed later). The surgery should proceed as follows.

- (1) Place two stay sutures at the deepest point of the natural 'U' of the rectosigmoid junction to mark the point where the side-to-side anastomosis will start later on.
- (2) Check that this maneuver can be performed tension free. If not, mobilize the sigmoid and descending colon up to the left colonic flexure (flexura lienalis). Ligate and divide the phreno-colonic ligament. Care must be taken to avoid splenic lesions.
- (3) Perform a right paracolic peritoneal incision to dissect the right ureter down to the bladder. Mobilize it carefully until it lies in an ideal position for implantation into the pouch.
- (4) Dissect the left ureter through the left paracolic incision. The blood supply of this ureter is more critical. Avoid any lesion of the longitudinal vessels running underneath the adventitia. Preserve accessory branches of the gonadal vessels that are running parallel and medial to the ureter.
- (5) Pull the ureter through a vessel-free window of the mesentery into an intraperitoneal position so that it meets the 'port of entrance' into the pouch at the level of the promontory without tension or kink.
- (6) Open the outlined bowel antimesenterically. Detubularize it over a total length of 15–20 cm with the electrocautery.
- (7) The side-to-side anastomosis starts at the deepest point using interrupted non-absorbable seromuscular sutures 4-0.
- (8) Move the pouch plate to the promontory. Again, check that the position is tension free.
- (9) Place one or two non-absorbable sutures through the periost of the promontory and the seromuscularis of the pouch from the dorsal site. The suture will be tied later when ureteral implantation is completed.
- (10) Complete the side-to-side anastomosis with a second line of mucosal suture (running suture 5-0 polyglactin).
- (11) Place four stay sutures to mark the length of the tunnel (3.5 cm) that facilitates antirefluxive ureteral implantation.
- (12) Make a cross-like incision into the seromuscularis by elevating the bowel wall using a finger and dissect a submucosal tunnel.
- (13) Create a port of entrance for the right ureter directly underneath the serosa of the mesosigmoid using a long small forceps and pull the ureter into the pouch. The course of the ureter should be nice and smooth without kinking or angulation.

- (14) Perform implantation of the left ureter in the same manner.
- (15) Subsequently, approximate the pouch-promontory fixation suture and check that both ureters enter the pouch without any obstruction or angulation.
- (16) Pull both ureters through their tunnel and shorten. Check capillary arterial bleeding at the ureteral stumps and spontaneous urine ejaculation. Exclude:
 - (a) insufficient vascularization;
 - (b) kinking;
 - (c) compression of the ureter inside the antirefluxive tunnel.

Split the ureteral stump 0.5 cm at 12 o'clock. Fix the ureter to the bowel seromuscularis with two 5-0 polyglactin sutures at 5 and 7 o'clock. Complete the anastomosis by a 12 o'clock and two 3 and 9 o'clock sutures with 5-0 polyglactin (magnification lenses) grasping the ureter and the bowel mucosa. Insert two 6 Fr stents into the ureter until a first resistance is realized, pull back again for 1 cm and fix at this level to the pouch plate with 5-0 polyglactin rapid. Insert the ends of the stents into the rectal tube through a side hole and pull out transanally. Reinsert the rectal tube. Fix the pouch plate to the promontory and close the pouch. Start pouch closure with interrupted polyglactin 4-0 sutures from caudal to cranial direction. (A multilayer [seromuscularis, submucosa] interrupted suture using 4-0 polyglactin has been shown to be safe in our experience for any suturing of large bowel.) Close the mesenteric windows. No intraperitoneal drainage is used. Cover the pouch with the greater omentum mobilized from left to right (preference of the author) and also freed from the stomach. Carefully fix ureteral stents and the rectal tube to the skin with separate sutures.

POSTOPERATIVE CARE

The patient is allowed to drink the same evening. Bowel movements usually start on the 5th day, at this time the rectal tube is removed. Otherwise gastrografine is given.

Fixation sutures of the stents are removed on days 8–10 and the stents will fall out spontaneously. Subsequently, ultrasound of the kidneys is performed normally showing a mild dilatation. Antibiotic treatment is continued for 3 weeks followed by prophylaxis with nitrofurantoin for another 4 weeks. Bicarbonate

or Uralyt U™ (MADAUS Company, Cologne) is used for early correction of a negative base excess that should not exceed -2.5 . Blood gas analysis is mandatory for the first few weeks. Ultrasound is repeated within 6 weeks (to be found normal).

COMPLICATIONS

Intraoperative complications

Intraoperative complications occur when the patient is too fat and the mesentery of the sigmoid too short to mobilize the sigmoid. If the ureters are too short after cystectomy, ureteral mobilization, and resection, they cannot be implanted tension free or without compromising the blood supply. These problems can be overcome by switching to a different strategy and performing another type of continent or incontinent diversion.

Complications occur when the pouch plate is already constructed and the ureters implanted but the pouch cannot be closed without tension as the mesentery turns out to be too short. In this case an ileum patch of adequate length should be used for augmentation.

Postoperative complications

Postoperative complications occur when stents are not draining or are blocked by blood clots (too high insertion with lesion of the papilla). If the patient has no clinical symptoms and the upper tract is not dilated during ultrasonography, a wait and see approach should be adopted. However, if the patient has symptoms and the kidneys are dilated, a percutaneous nephrostomy tube should be inserted immediately. A non-functioning splint stent should never be irrigated.

In patients with peritonitis early revision is the method of choice, in the case of a pouch leakage a right transverso-cutaneostomy should be performed. The small pelvis should be drained.

Late complications

Persistent asymptomatic dilatation can be observed in a small number of renal units over several years and requires no treatment. In children with even asymptomatic upper tract dilatation ureter reimplantation is indicated.

Late ureteral obstruction was found in 7.2% of patients mainly in dilated and fibrotic ureters, e.g. in exstrophy patients with unsuccessful closure. If the pouch-fixed to the promontory with sutures-loose this

fixation due to disruption of the suture kinking of the ureters. This may occur. Temporary percutaneous nephrostomies are the method of choice followed by ureteral reimplantation. The technique of the serous-lined extramural tunnel³ is recommended for ureteral reimplantation in dilated and fibrotic ureters.

Serous-lined extramural tunnel

In the majority of cases the left ureter is the dilated one. In case of a dilated ureter, a relaparotomy is performed and the pouch and dilated ureter are identified. The sigma is mobilized, a third sigmoid loop is approached to the pouch and detubularized. Non-absorbable 4-0 interrupted seromuscular sutures are used for the first row of the side-to-side anastomosis (close to the mesentery). The dilated left ureter is placed in the so-created groove and the bowel borders closed over the ureter incorporating it into the posterior pouch wall. The definitive ureteral implantation into the suture line is performed using muco-mucous sutures with 5-0 polyglactin sutures.

Bilateral dilatation

In bilateral dilatation the pouch is opened and the obstructed ureters are identified. The mucosa suture line is opened and the right ureter embedded in a new channel. For the left ureter the implantation technique previously described is used.

Incontinence

Cerebroscclerosis and Morbus Alzheimer may cause incontinence at a later stage. For these patients (uretero-uretero-cutaneostomy [UUCS] wrapped by the greater omentum) is less invasive, well tolerated, and can even be performed laparoscopically.

TIPS AND TRICKS

It should be remembered that the left ureteral dissection and implantation is the more critical. On the right side branches from the gonadal artery – crossing the vena cava – are forming a capillary network as accessory ureteral blood supply. In contrast, on the left side branches of the gonadal vessels are running parallel and medial with further branches that can be injured by a cranial and more extended ureteral dissection.

Creation of a wide mesenteric window is important to transfer the left ureter intraperitoneally so that it enters the pouch nicely and smoothly. Ureteral dissection, separation, and biopsy are followed by intubation. The stents are removed again before the ureter pouch is anastomosed. Capillary arterial bleeding from the stumps (magnification loop systems 2.5) and spontaneous urine ejaculation are checked before the stents are reinserted and fixed.

Stay sutures are almost always used to mark the length of the submucous tunnel. When using the serous-lined extramural tunnel technique the first row of the side-to-side anastomosis with non-absorbable seromuscular interrupted sutures must be placed carefully close to the mesentery; the diameter of the tunnel can be adapted to the dilatation and wall thickness of the ureters.

It should be noted that the blood supply of the large bowel is different from that of the small bowel which is commonly used in urology. The vasa recta arising from the arcade of Rioli are short vessels which circumferentially reach the Tenia libera from both sides. Between the vasa recta the sutures can be placed in order to increase the diameter of the tunnel. This is a common and well known problem in the serous-lined extramural tunnel technique using small bowel where a "T" becomes necessary.

Dissection of the greater omentum is time consuming. However, it protects the pouch from urinary leakage and the bulk fills the empty right fossa obturatoria after lymphadenectomy (risk for small bowel adhesions and mechanical ileus).

'TO DO AND NOT TO DO'

Yearly colonoscopy starts 5 years postoperatively and should be done by the urologist and not the gastroenterologist. The ureteral implantation side normally is prominent and looks like a papilla. In two of this author's patients the 'polyps' interpreted as tumor were endoscopically removed. A percutaneous nephrostomy had to be performed as an emergency procedure followed by ureteral reimplantation. Nevertheless, a cold superficial biopsy is indicated if a real polyp is found. Polyps can not only occur at the implantation site, but also elsewhere in the pouch. When histological dysplasia is diagnosed short

time check-ups are mandatory. In G2 or G3 lesions wide excision of both ureters and conversion into another form of urinary diversion is indicated. The transverse ascendens pouch (TAP) would be the method of choice.

Woodhouse et al⁶ described a well known problem in patients with a rectosigmoid pouch well functioning over many years. He widely excised the orifices and successfully reimplanted the pouch. Conversion of a colonic conduit with antirefluxive ureteral implantation into a rectosigmoid pouch is a safe method that we have performed in a couple of cases.

REMARKS

The sigma-rectum pouch was first performed in 1990 in a 20-year-old woman with ureterosigmoidostomy following anterior exenteration due to a gynecologic tumor. The ureteral implantation of the right solitary kidney had become obstructed and a nephrostomy was inserted. Conversion into a rectosigmoid pouch was performed together with creation of a cecal neovagina. The patient remains happy with a steady partner.

Urinary diversion using the rectosigmoid pouch (Mainz pouch II) is a simple and reproducible form of urinary diversion. It is also easy to teach as each step is performed under direct vision. Even though a certain number of modifications have been published during the past 16 years the original method described here is still our method of choice.

Contraindications should be respected. Compliance of the patient is of utmost importance. Antacidotic treatment is a 'conditio sine qua non' as well as regular colonoscopies.

RESULTS

The Mainz pouch II was used in 123 patients (49 females and 74 males), mean age 43.6 years (range 1–73) for bladder malignancy $n = 92$ and benign disease $n = 31$. Follow-up was for more than 12 months (mean 46.2 months). Day and night continence rates were 97% and 95%, respectively. In 14 preoperative dilated renal units reimplantation was performed successfully. In 36 children with a long-term follow-up of up to 10 years the same excellent results were achieved.

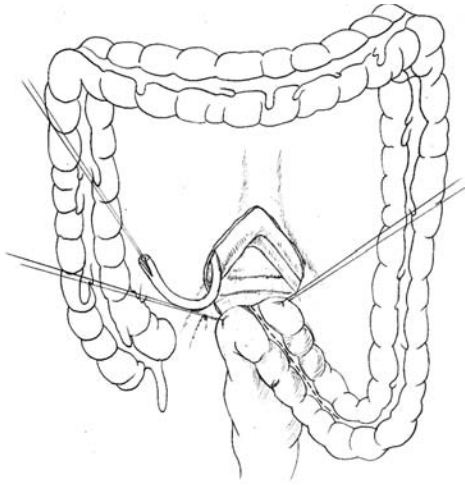


Figure 46.1 Right ureter dissected, sigmoid loop to be fixed later on to the promontory without tension.

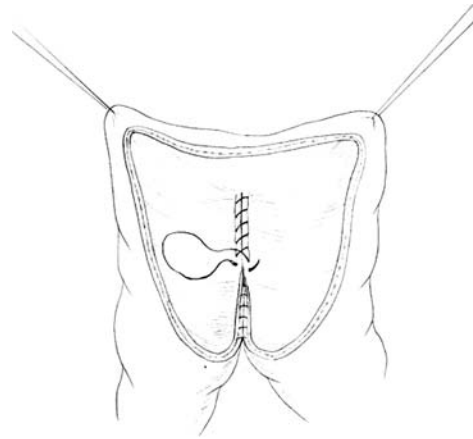


Figure 46.4 Pouch plate anastomosis completed by a running mucosa suture.

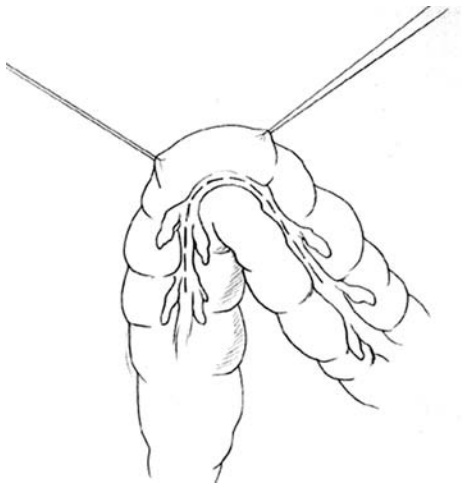


Figure 46.2 Line of detubularization.

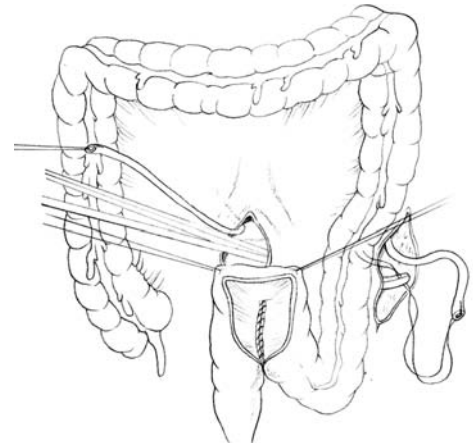


Figure 46.5 Dissected left ureter brought intraperitoneally through a mesenteric window in the mesosigmoid.

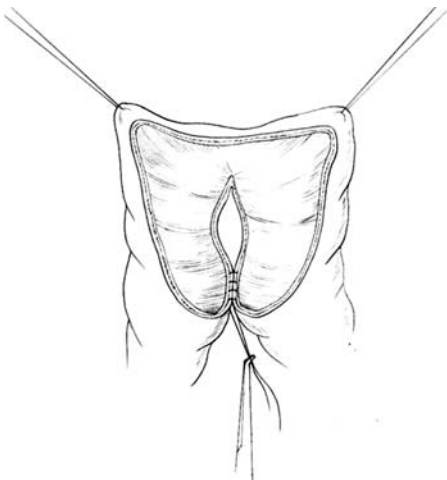


Figure 46.3 First interrupted seromuscular suture line starts from distal in a proximal direction.

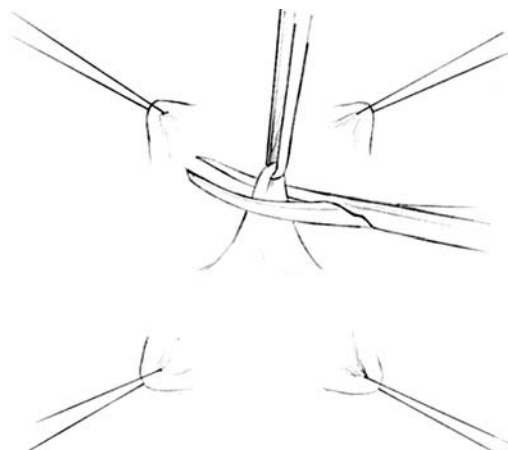


Figure 46.6 Ureteral implantation. Tunnel marked by stay sutures, mucosa incised.

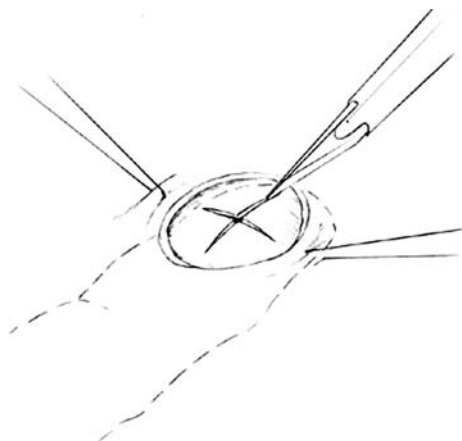


Figure 46.7 Cross-like incision of underlying seromuscularis.

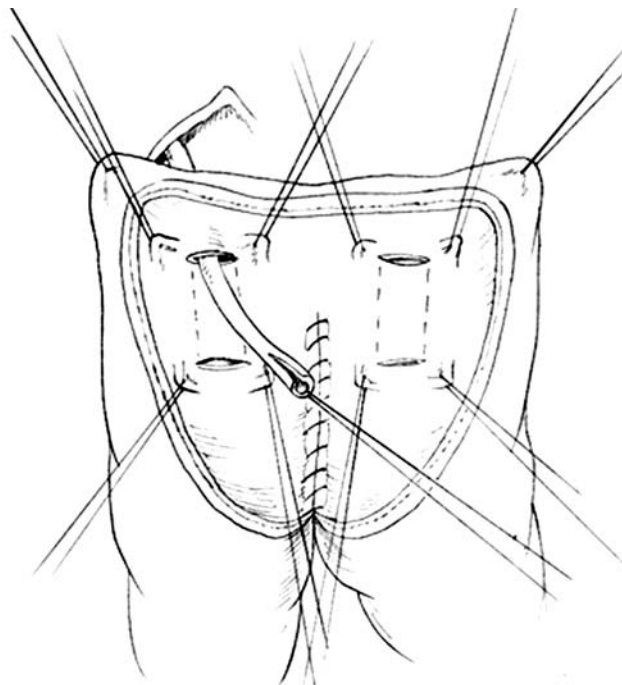


Figure 46.10 The right ureter is pulled into the pouch.

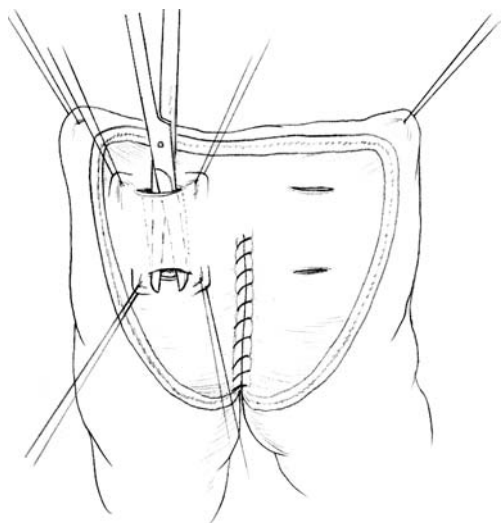


Figure 46.8 Dissection of tunnel.

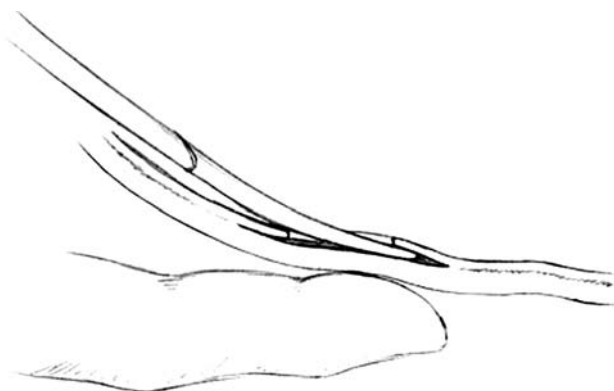


Figure 46.9 Tunnel dissection is facilitated using the left digital finger.

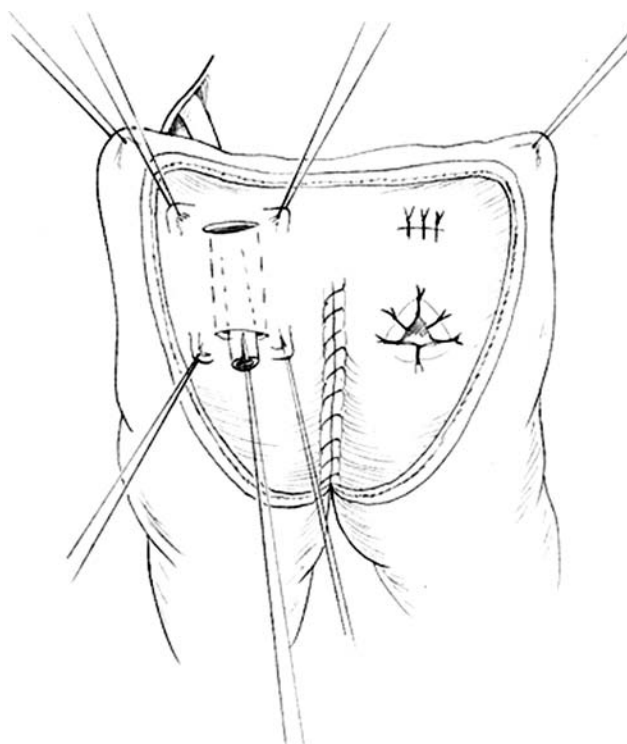


Figure 46.11 Both ureters inside the pouch. Check final pouch position and ureteral length before ureteral implantation is completed.

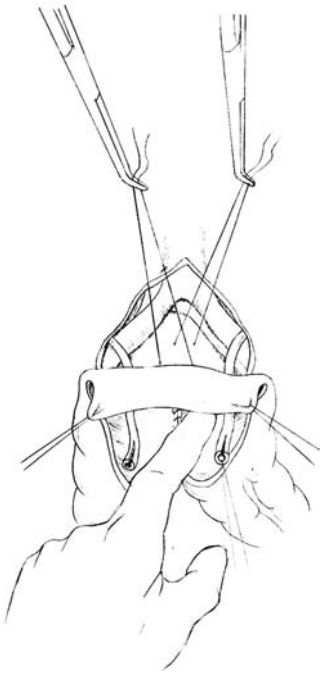


Figure 46.12 Completed ureteral implantation.

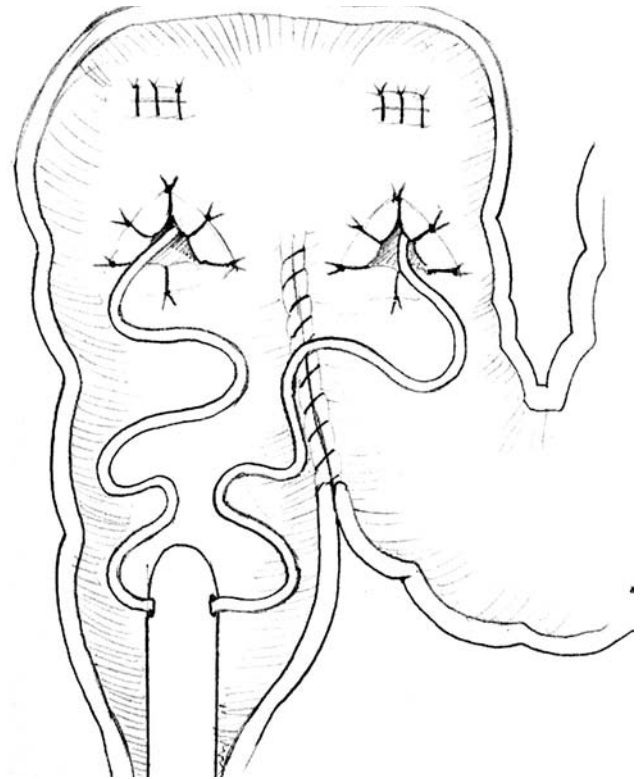


Figure 46.14 Splints inserted into the rectal tube.

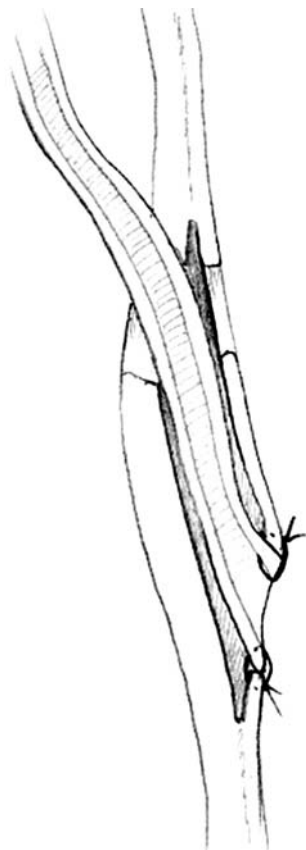


Figure 46.13 Lateral view of the tunnel.

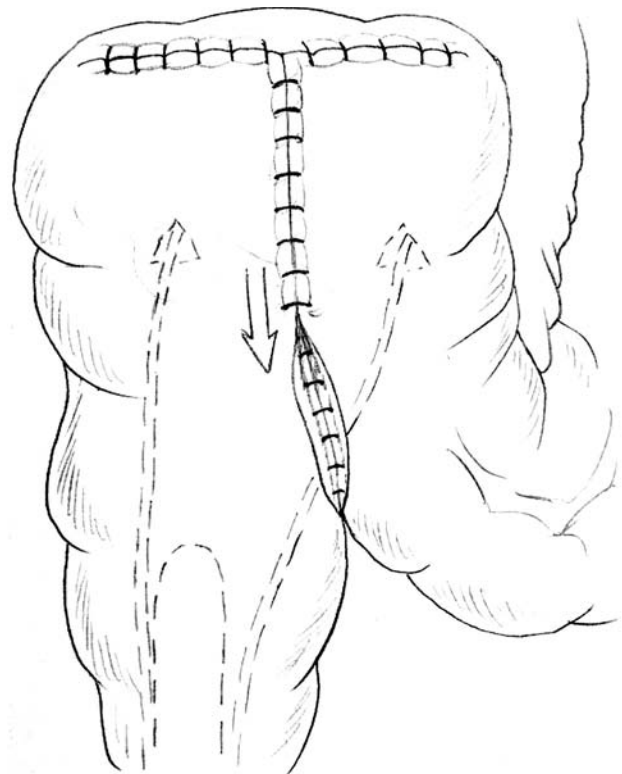


Figure 46.15 Pouch anastomosis is completed. Rectal tube is reinserted.

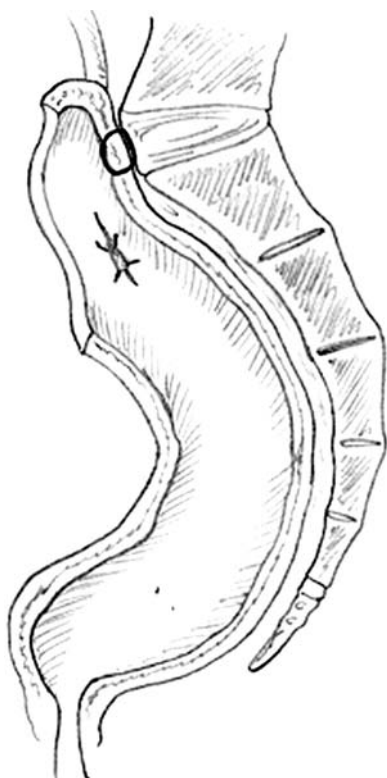


Figure 46.16 Lateral view of the pouch position.

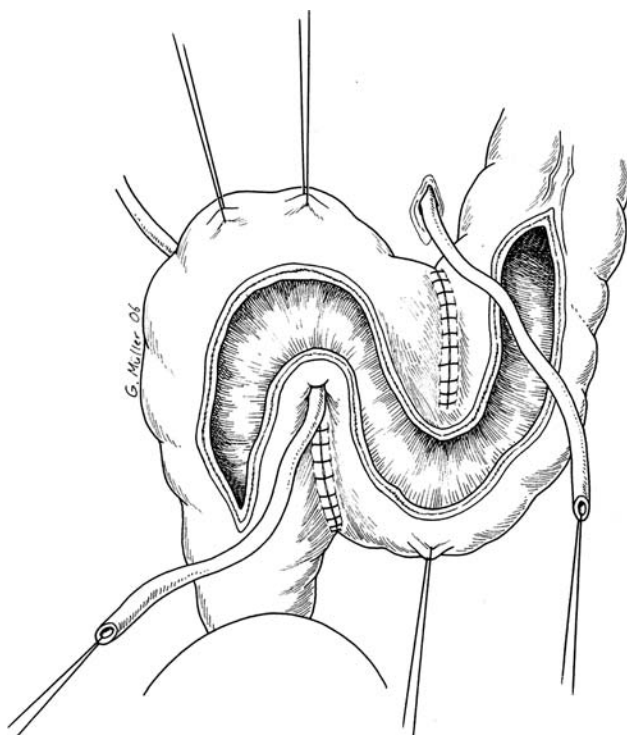


Figure 46.18 Reimplantation of both obstructed ureters using the serous-lined extramural technique.

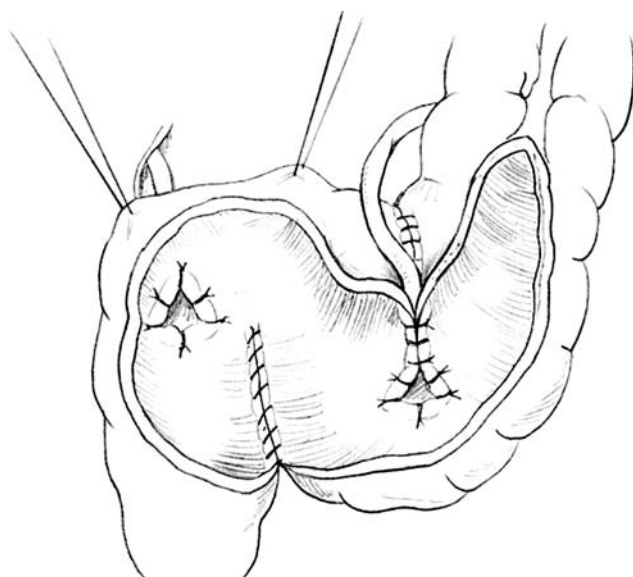


Figure 46.17 Reimplantation of an obstructed left ureter using the serous-lined extramural tunnel technique.

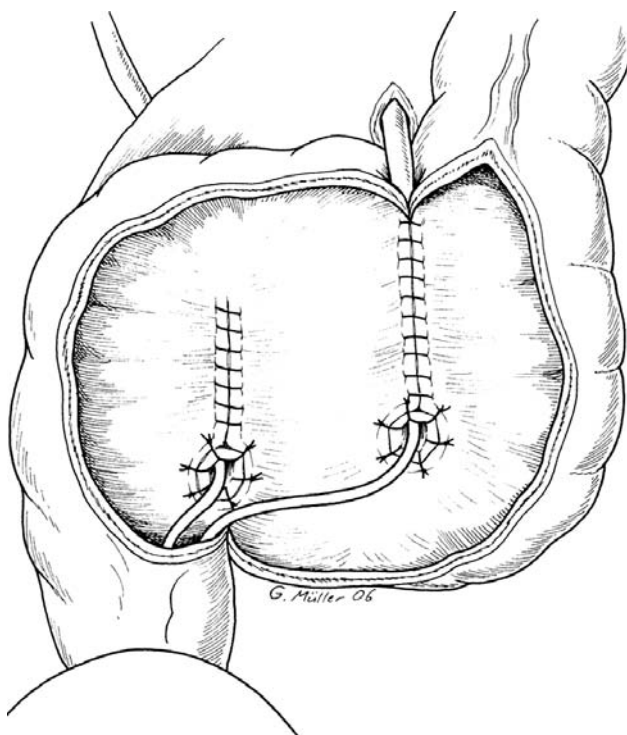


Figure 46.19 Reimplantation completed.

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47 Artificial urinary sphincter implantation in the adult male

Drogo K Montague

INDICATIONS

Urinary incontinence is an unfortunate outcome after prostatectomy occurring in 8.4% of men in one series at 18 months after radical prostatectomy,¹ and in 0.5% of men in a large, multicenter series following transurethral resection of the prostate.² When this incontinence is shown by urodynamic study to be secondary to intrinsic urethral sphincteric deficiency, artificial urinary sphincter (AUS) implantation is often indicated.

While urinary incontinence is often associated with neurogenic bladders of varying types, AUS implantation is not usually indicated since it will not provide relief for incontinence associated with detrusor hyperreflexia. In cases of congenital (myelodysplasia) or acquired caudal equina syndromes, the bladder and sphincter are often both denervated, and AUS implantation may play a role in managing selected cases of this nature.

PREOPERATIVE PREPARATION

The patient should be free of any urinary tract, systemic, or skin infections in the operative area. Urethral obstruction such as stricture should be ruled out by preoperative cystourethroscopy. Video urodynamic studies are done as necessary to establish the diagnosis and to rule on the appropriateness of AUS implantation. Broad spectrum intravenous antibiotics (e.g. gentamicin and vancomycin) are given 1 hour before the incision is made.

THE ARTIFICIAL URINARY SPHINCTER

The AUS (AMS 800™, American Medical Systems, Minnetonka, MN, USA) consists of three components: a cuff, a pressure regulating balloon (PRB), and a pump-control assembly unit. These devices are implanted separately and then joined by two connectors (Figure 47.1). In men with postprostatectomy urinary incontinence, the cuff is implanted around the bulbous urethra. The PRB is



Figure 47.1 AMS 800™ Artificial Urinary Sphincter, American Medical Systems, Minnetonka, MN, USA. Used with permission of American Medical Systems.

implanted next to the bladder, and the pump is implanted in the scrotum.

PRBs come in three pressure ranges: 51–60, 61–70, and 71–80 cmH₂O. Cuffs come in various sizes increasing in circumference by 0.5 cm increments beginning at 4 cm and going to 8 cm and then by 1 cm increments up to 11 cm. In the control assembly above the pump are valves that control direction of flow, a delay fill resistor, and a deactivation button.

When the AUS is active, fluid flows from the PRB into the cuff until cuff and PRB pressures are equal. This pressure, which is safe for the adult male bulbous urethra, produces continence by providing closure of the urethra. When bladder pressure increases because

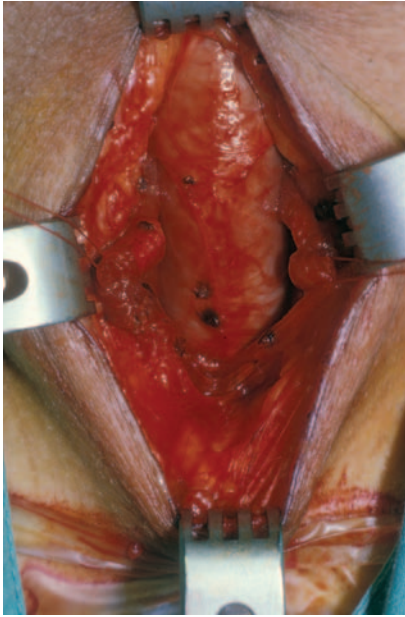


Figure 47.2 Partial division of the bulbocavernosus muscles.

of increases in intra-abdominal pressure, pressure in the PRB increases in a parallel fashion thereby providing protection against stress incontinence.

To void, the man squeezes the pump in his scrotum. The fluid in the pump goes into the PRB; when the pump is released, it draws fluid out of the cuff. This maneuver is repeated until the pump stays collapsed indicating complete emptying of the cuff. As the patient voids, fluid returns down a pressure gradient from the PRB through the pump and into the cuff until PRB and cuff pressures are again equal. A delay fill resistor in the control assembly slows this return of fluid so that the patient has time to empty his bladder.

The AUS can be deactivated at any time by squeezing the pump until the cuff is empty. When the pump is nearly full via return of fluid from the PRB, the deactivation button is pressed and this prevents refilling of the cuff. The AUS is initially deactivated, usually for 6 weeks, following its implantation. This allows urethral swelling under the cuff and swelling and tenderness around the scrotal pump to subside before the device is activated. Device activation is done by forcefully squeezing the pump until it suddenly collapses. This activates the AUS and allows fluid to flow from the PRB through the pump into the cuff until PRB and cuff pressures are equal. The AUS can be deactivated at any time again in the future, for example, if the patient needs cystoscopy or urethral catheterization.

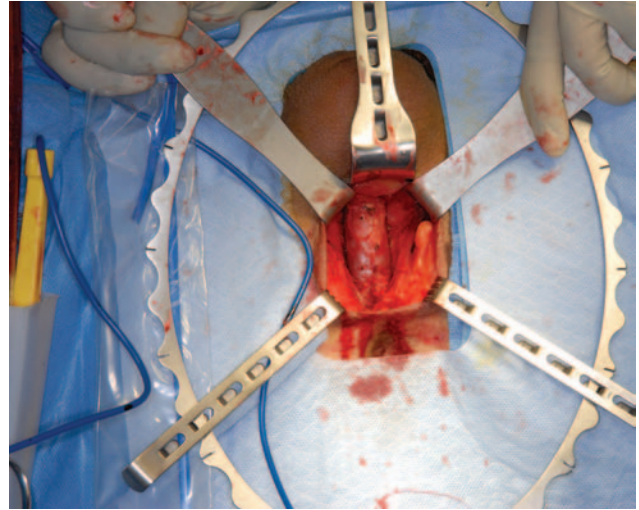


Figure 47.3 Exposure of the bulbous urethra after completely dividing and reflecting the bulbocavernosus muscles.

OPERATIVE TECHNIQUE

The patient is placed in the lithotomy position, and prepped and draped. Paper drapes are preferred since unlike cloth drapes they are not permeable to bacteria when wet and they do not contain lint. An 18 Fr Foley catheter is inserted and connected to closed sterile drainage. An incision 8 cm in length is made along the midline perineal raphe. The bulbocavernosus fascia and muscles are divided in the midline (Figure 47.2) exposing the bulbous urethra (Figure 47.3).

Although the AUS cuff is only 2 cm in width, exposure of 8 cm of urethra allows the urethra to be first rotated to the patient's right so that the posterior attachments of the bulbous urethra to the inferior fascia of the urogenital diaphragm can be taken down by sharp dissection under direct vision (Figure 47.4). This maneuver is then repeated by rotating the urethra to the patient's left (Figure 47.5) until the urethra is completely detached from the fascia running between the crura. A common mistake in artificial sphincter implantation is to expose a limited segment of urethra and then blindly insert a right-angle clamp through the posterior urethral attachments. When this clamp is spread, the attachments are torn sometimes injuring the posterior aspect of the urethra. This may lead to early urethral cuff erosion.

The cuff sizer supplied with the AUS is used to determine the circumference of the urethra (Figure 47.6) which in the case illustrated falls between the 5.5 and 6 cm marks. When the measurement falls between cuff sizes, the larger size should always be chosen; in this

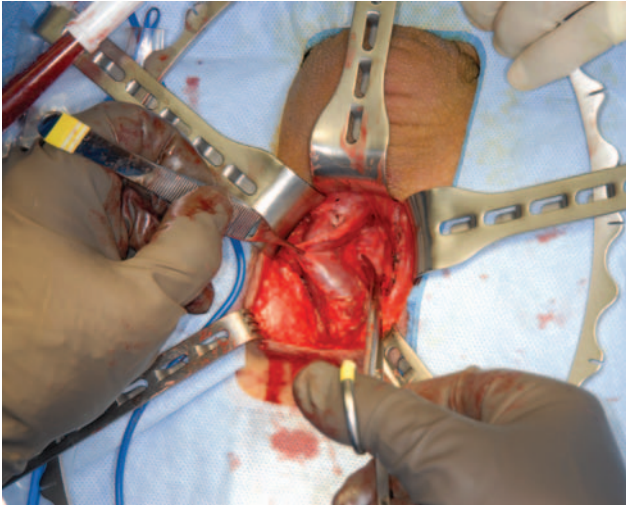


Figure 47.4 Sharply dividing the posterior urethral attachments on the patient's left side.

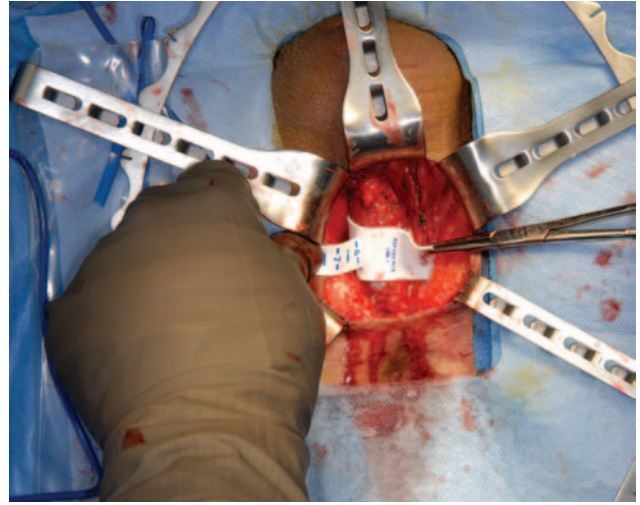


Figure 47.6 Using the cuff sizer to determine the urethral circumference.

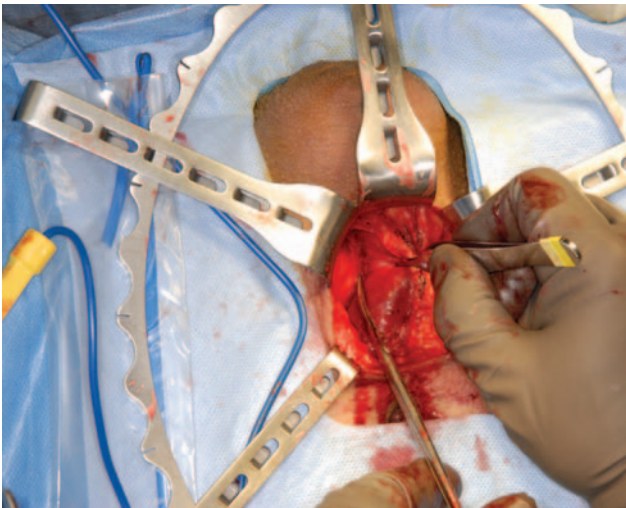


Figure 47.5 Sharply dividing the posterior urethral attachments on the patient's right side.



Figure 47.7 Perforating the transversalis fascia in the floor of the external inguinal ring.

case a 6 cm cuff was used. The goal should be to use a cuff that when it is open produces no constriction of the urethra during endoscopic viewing. A late complication of AUS implantation is urethral atrophy, and this may result from a cuff that is too tight.

A second transverse incision is made over the external inguinal ring on the side on which the pump is to be inserted. The surgeon's index finger is inserted into the inguinal ring and scissors are used to perforate the transversalis fascia which forms the floor of the external ring (Figure 47.7). The point chosen for this perforation is just over the pubic bone and medial to the surgeon's finger. This protects the spermatic cord which is located laterally. If the external inguinal ring

cannot be located because of previous surgery, a point just above the pubic tubercle is chosen for this perforation of the fascia. The bladder must be completely empty to avoid its perforation with this step. When the fascia is completely perforated, the surgeon's finger will enter the retropubic space and the surgeon should be able to feel the back of the symphysis pubis as well as the empty bladder (Figure 47.8). Care must be taken to ensure that the fascia is completely perforated and the retropubic space is entered. Otherwise, if the PRB is inserted between layers of the fascia and filled with the requisite amount of fluid, it will not be able to expand freely. The pressure in the balloon will be considerably higher than intended, and this may lead to



Figure 47.8 Palpation ensures that the retropubic space has been entered.

urethral cuff erosion. Also, if the PRB is located where it should be, next to the bladder, it will respond in a similar fashion to the bladder when intra-abdominal pressures increase thus protecting against stress incontinence.

Silicone is semipermeable and thus the AUS must be filled with an isotonic solution. Normal saline can be used, but since AUS trouble shooting³ is aided by filling the prosthesis with contrast, an isotonic solution of contrast is prepared. This is done by diluting contrast with sterile water according to instructions supplied in directions that come with the AUS prosthesis. Filling the AUS with hypotonic or hypertonic fluid will lead to transfer of water into or out of the system, and since the AUS is volume dependent, this can lead to malfunction. Care must be taken to make certain that this fluid does not become contaminated with lint, tissue particles, blood, or anything else. Such material may plug the delay fill resistor which is part of the AUS control assembly located above the pump, and this may also lead to malfunction of the device.

The cuff is filled with isotonic contrast to displace air, and then the contrast is removed since the cuff is empty when it is implanted. The same is done for the PRB. A PRB with a pressure range between 61 and 70 cmH₂O is used by most implanters for bulbous urethral implants. The AUS pump is then filled with isotonic contrast. This is done by holding the pump tubing in the contrast solution and cycling the pump until it is full and the air has been displaced.

The cuff is then passed behind the urethra (Figure 47.9) and fastened in place by passing the cuff tubing through the hole in the tab at the end of the cuff and then allowing the tab containing this hole to slip into

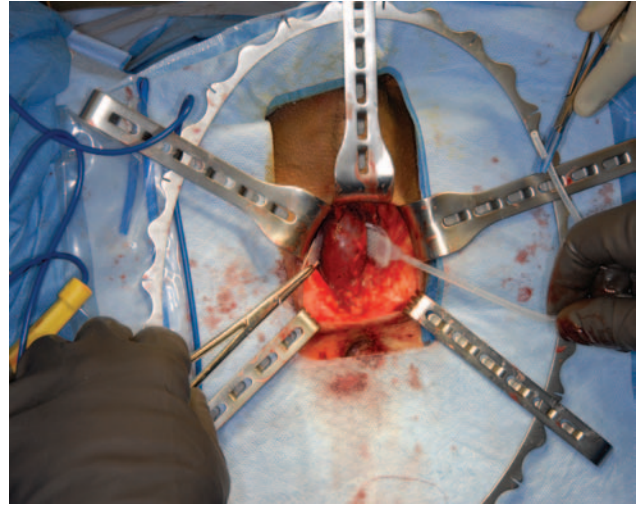


Figure 47.9 Passing the cuff behind the urethra.

the slot behind the tubing hub (Figure 47.10). If the tab does not slip into this slot, the cuff may become unfastened. The cuff tubing is loaded onto the tubing passer which then transfers the cuff tubing from the perineal incision (Figure 47.11) up to the inguinal incision (Figure 47.12). This tubing should emerge in the inguinal incision between the anterior rectus fascia and Scarpa's fascia.

A sub-dartos pouch for the pump is created in the scrotum by passing ring forceps beneath Scarpa's fascia down to the bottom of the scrotum. The forceps are then spread to create this pouch for the pump (Figure 47.13). The pump is then carried on the surgeon's finger until it can be grasped through the upper scrotal skin and then pulled down to the bottom of the scrotal pouch (Figure 47.14).

The empty PRB is then placed into the retropubic space. This maneuver is aided by using a nasal speculum with long blades to maintain the fascial opening leading to this space (Figure 47.15). The PRB is then filled with 22 ml of isotonic contrast. Inspection and palpation ensure that the balloon is positioned deep to the fascia and that the hub which forms the transition between the balloon and the tubing is exiting directly through the fascial defect. If the tubing hub is located behind or lateral to the body of the balloon, the tubing will wear a groove in the balloon wall resulting in early PRB failure. The connection between the PRB and the pump is then made with a straight connector and a connection between the cuff and the pump is made with a right-angle connector (Figure 47.16). In making these connections, the tubing should be cut transversely so that it will fit more securely into the connector. The tubing on each end should be fully inserted to the central stop of

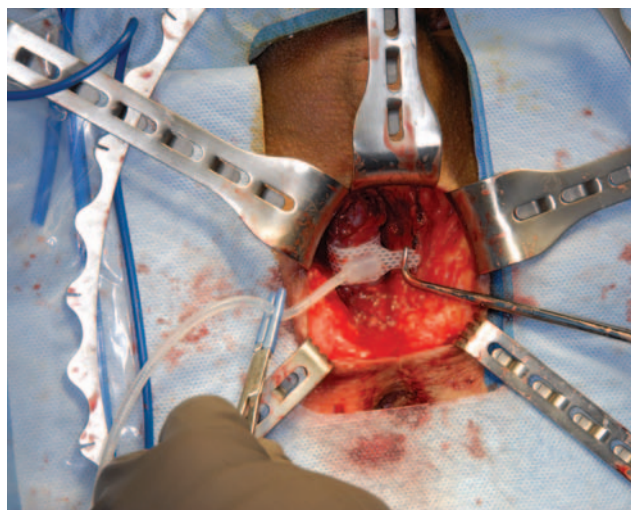


Figure 47.10 Fastening the cuff.



Figure 47.12 Receiving cuff tubing in the inguinal incision.

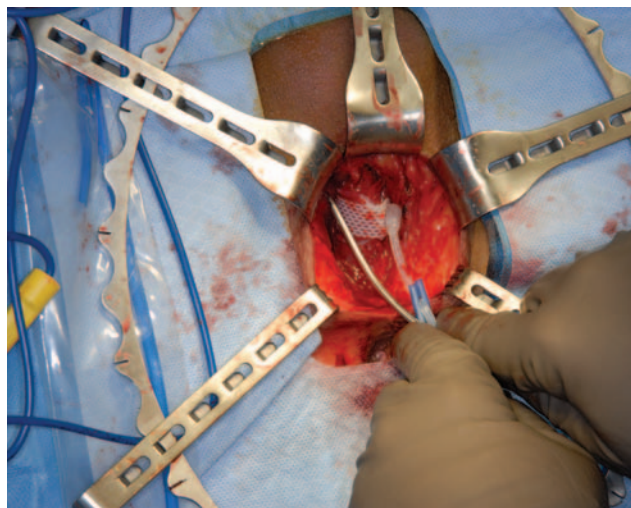


Figure 47.11 Transferring cuff tubing from the perineal incision.



Figure 47.13 Creating a sub-dartos pouch for the pump.

the connector. Finally, the connector rings should be completely seated (not on an angle).

Scarpa's fascia in the inguinal incision is closed over the tubing and both connectors with running absorbable suture. The skin in this incision is then closed by a running subcuticular absorbable suture. The perineal incision is closed by approximating the bulbocavernosus muscles and fascia over the cuff with running absorbable suture. Running absorbable suture is then used to close Colles' fascia. The skin is also closed with a running absorbable subcuticular suture. Having all parts of the AUS, including tubing and connections, beneath the fascia protects the device against infection in the event of a superficial wound infection and separation of the skin edges.

At the conclusion of the implant procedure, the pump is cycled until it stays collapsed indicating

complete emptying of the cuff. The PRB slowly sends fluid into the pump until it is almost full. The deactivation button in the control assembly above the pump is then depressed to deactivate the AUS and prevent the cuff from refilling with fluid.

POSTOPERATIVE CARE

We do this surgery in an ambulatory care surgery center. The patient leaves the center on the next morning following catheter removal. We instruct the patient to pull the pump down as far as possible in the scrotum three times a day. A low position for the pump in the scrotum makes it easier to use. Six weeks after implantation the patient returns for a postoperative



Figure 47.14 Positioning the pump in the most dependent portion of the right scrotum.



Figure 47.15 Placing the empty pressure regulating balloon into the retropubic space.

visit. If both incisions are well healed, urinalysis shows no blood or infection, and the tissues surrounding the scrotal pump are normal, the device is ready for activation.

Activation is done by forcibly and quickly squeezing the pump. This causes the deactivation cylinder, which is part of the control assembly above the pump, to change position and the pump then collapses. The PRB will be able to return fluid to the pump and then through the pump to the cuff until PRB and cuff pressures are equal. The patient is then instructed on how to open the AUS, using the pump, for voiding.

We have the patient return 6 weeks later for another postoperative visit. At this visit an X-ray of the AUS is



Figure 47.16 The completed connections between the pressure regulating balloon and pump (straight connector) and the cuff and pump (right-angle connector).

obtained while the cuff is closed. The patient is then asked to open the cuff and a second X-ray is taken. This set of films is obtained for baseline purposes and will serve as a reference if the patient returns in the future with recurrent incontinence. At the time of this second postoperative visit the patient is questioned about his use of the device, the degree of control he has, what he is doing when he leaks, and the number of pads he wears per day if any. If the patient fails to achieve the treatment goal (one pad or less per day), or if he achieves this goal but becomes more incontinent in the future, we employ our troubleshooting protocol.³

RESULTS

In an editorial comparing results of AUS implantation with collagen injection for the treatment of postprostatectomy urinary incontinence, we found five reports with a total of 286 AUS patients. These five case series had mean follow-ups of 18, 23, 37, 41, and 44 months. Using a commonly accepted definition of success as the use of one pad or less per day, 216 (76%) of the patients were successful.⁴

In a later report of a single case series, 113 men who had undergone AUS implantation for postprostatectomy incontinence had a mean follow-up of 73 months (range 20–170 months). Using the same definition of success, 64% of patients remained dry (1 pad or less per day). Fourteen (12%) of these patients had undergone surgical revision.⁵

AUS implantation remains the gold standard for the treatment of postprostatectomy urinary incontinence.

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48 Bulbous urethral slings

Bradley A Erickson and Anthony J Schaeffer

INTRODUCTION

The number of men undergoing surgery for prostate cancer continues to rise, with over 60 000 radical prostatectomies having been performed in the US in 2005 alone. Dramatic improvements in surgical techniques aiming to minimize postoperative incontinence have been made, but the percentage of men seeking help for postprostatectomy incontinence is still surprisingly high, reported at nearly 10%.¹ Incontinence has been shown to severely impact quality of life in these men;² thus, helping them is of the utmost importance. This concern has heightened in the prostate specific antigen (PSA) era, as men are being treated for prostate cancer much earlier in life and living much longer with incontinence related problems.

The bulbourethral sling is used for the treatment of male urethral sphincter deficiency, which occurs commonly after prostate surgery. First described in 1998,³ the bulbourethral sling procedure has shown success rates similar to those of the artificial urinary sphincter (AUS). While the AUS remains a popular and effective treatment for postprostatectomy incontinence, the bulbous sling has some distinct advantages over the sphincter. The sling procedure allows for physiologic voiding and has no moving parts that can potentially fail. It is also less invasive, costs significantly less than the AUS (average cost 500 US dollars versus 6000 US dollars), and may have the potential for fewer problems with postoperative urethral erosion. It is also a useful alternative for patients without the manual dexterity or mental capacity necessary to operate an AUS.

The bulbourethral sling procedure involves the placement of synthetic, non-absorbable sling material beneath the bulbar urethra that is secured in place by retropubically coursing polypropylene sutures tied across the anterior rectus fascia. The tension on and support of the ventral aspect of the bulbar urethra by the sling provides the continence mechanism.

PREOPERATIVE WORK-UP

The evaluation of a male patient considering a sling procedure should begin with a thorough clinical history

and complete voiding diary. Particular attention should be paid to the patterns of incontinence, specifically asking about any periods of dryness, whether the incontinence has stabilized, and its overall severity. A complete physical examination, including a thorough neurologic examination, should be done in both the supine and erect positions.

Postprostatectomy urodynamic studies have shown intrinsic sphincter deficiency to be the etiology of incontinence in the majority of men. However, a significant percentage will have bladder neck contractures, detrusor instability, and hypocontractile bladders.⁴ Therefore, all patients should undergo urodynamic and cystoscopic evaluation before a sling procedure can be performed. Cystoscopy can also reveal other urethral anomalies, such as urethral stricture disease and urethral false passages, all of which would need to be addressed prior to sling implantation.

INDICATIONS

Most men undergoing bulbourethral sling surgery have postprostatectomy incontinence. In this population, it is prudent to wait at least 6 months after surgery and until the patient's incontinence has stabilized before implantation should be considered. However, any condition that leads to inadequate urethral resistance is a potential candidate for sling surgery. Bulbourethral slings have been placed in patients after transurethral resections of the prostate and pelvic fractures, and in patients with neurogenic bladders from trauma or meningomyeloceles, and other congenital problems such as exstrophy-epispadias complex.

CONTRAINDICATIONS

Voiding after bulbourethral sling procedures is physiologic; therefore, a functional bladder and an intact urethra must be verified before placement. Patients with recurrent and unstable urethral stricture disease should not undergo a sling procedure. If urodynamic studies show a hypocontractile bladder, clean intermittent catheterization (CIC) will usually be required

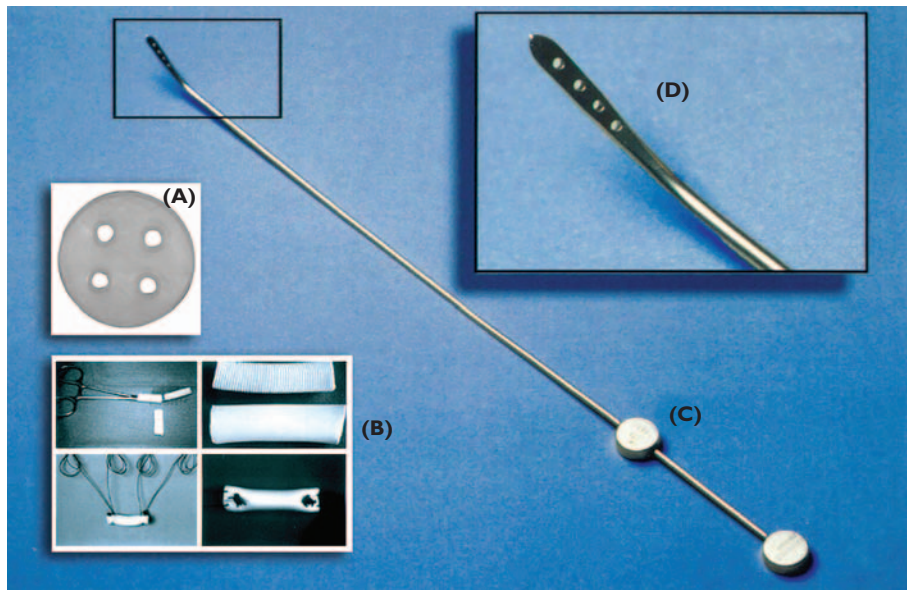


Figure 48.1 (A) Hewson ligament button. (B) Construction of the bilayered bolsters with vascular graft material. (C) Stamey needle showing the four holes (D) through which the sutures will be placed.

after sling placement. If the patient will not tolerate CIC, it is recommended that an AUS be placed instead. Patients whose bladder neck contracture or urethral stricture disease has been treated should wait at least 3–6 months to confirm disease stabilization. Patient histories that include detrusor instability, hyperreflexia, stage D prostate cancer, prior radiation therapy, or prior infected prosthesis should be noted, but none are absolute contraindications to the procedure provided concomitant sphincteric deficiency exists.

ALTERNATIVE TREATMENTS

Men who experience postprostatectomy incontinence are often prescribed pelvic floor (Kegel) exercises to help strengthen the pelvic floor musculature. However, it is unlikely that Kegel exercises alone will lead to a significant improvement in continence if changes are not seen by 6 months. Urethral bulking agents inserted both transurethraly and transperineally have shown some moderate short-term success, but long-term outcomes are poor. The artificial urinary sphincter (AUS), described in detail in Chapter 47, has been implanted since 1972 and is highly effective. Recent improvements in the surgical technique and the introduction of narrow-backed cuffs have improved success rates of the AUS; however, revisions are still sometimes necessary due to erosion and mechanical problems.

SURGICAL TECHNIQUE

Materials

Materials for the bulbourethral sling procedure are listed below.

- Urethral bolsters – two layers, prepared on surgical field using graft material
 - Outer layer: tetrafluoroethylene (Gortex® Vascular Graft, W.L. Gore & Associates, Inc. Flagstaff, AZ) vascular graft, 6 mm diameter, cut to 4 cm in length (Figure 48.1)
 - Inner layer: woven polyester vascular graft (Cooley Veri-Soft; Meadox Medical, Oakland, NJ), 6 mm diameter, cut to 4 cm in length (Figure 48.1)
- Suture: 1.0 polypropylene (Nylon® suture, Ethicon, Somerville, NJ) suture (Figure 48.1)
- Hewson ligament buttons (Smith & Nephew, London, England) (Figure 48.1): 19 mm polyethylene
- Stamey needle (Cook Urological, Spencer, IN): four hole, 60°, extra long (Figure 48.1)
- Percutaneous suprapubic tube
- Dual channel urethral catheter (7 Fr) for intraoperative urodynamics
- Irrigation: containing gentamicin, bacitracin, and a cephalosporin. This is to soak the sling material prior to implantation and is used liberally throughout the procedure.

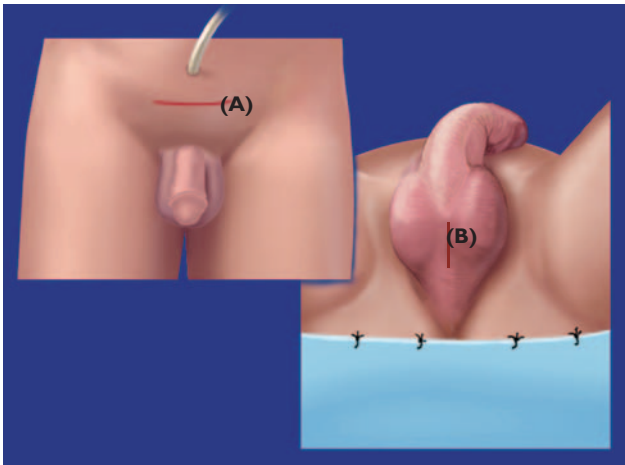


Figure 48.2 The suprapubic (A) and perineal (B) incision sites are marked. The suprapubic tube has been placed with cystoscopic guidance. Courtesy of the American College of Surgeons. Cine-Med Inc © Copyright 2004. All rights reserved. Reprinted with permission.

Procedure

A urine culture performed at least 3 days prior to the scheduled surgery should show no growth. After the induction of general or spinal anesthesia, the patient is placed in the dorsal lithotomy position. Parenteral antimicrobial prophylaxis, usually with vancomycin and an aminoglycoside, is given preoperatively. The abdomen and perineum are shaved and a thorough, 10 minute cleansing of the perineal and suprapubic areas with betadine solution is then performed. A towel is then secured on the inferior portion of the perineum with suture or staples to prevent fecal contamination during the procedure. The remaining drapes are then placed before a final prep with Duraprep® (3M, St Paul, MN) is completed.

Cystoscopy is performed to reconfirm the absence of a bladder neck contracture or other urethral anomaly that would prevent implantation. With the cystoscope observing the dome of the bladder, a percutaneous suprapubic tube is then inserted and sutured into place. A Foley catheter is then inserted to enhance the identification of the urethra.

The perineal incision site is identified by palpating the apex of the ischial-symphyseal arch and the bulbar urethra, and then marked. The transverse suprapubic incision site is marked just above the symphysis pubis (Figure 48.2). A single transverse suprapubic incision, approximately 5 cm in length, is made and carried down to the anterior rectus fascia. A midline perineal incision, usually about 4 cm in length, is then made to the level of the Colles' fascia with care to avoid disrupting the underlying bulbocavernosus muscle.

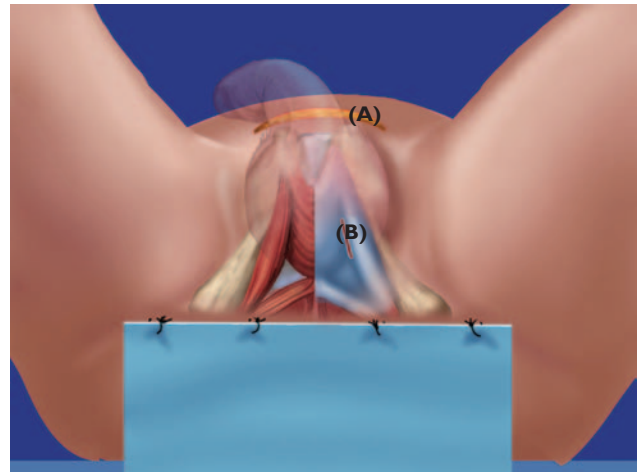


Figure 48.3 The suprapubic incision has been made (A). Colles' fascia overlying the bulbourethral musculature is incised lateral to the musculature and medial to the ischial arch (B). Finger dissection exposes the perineal membrane bilaterally. Courtesy of the American College of Surgeons. Cine-Med Inc © Copyright 2004. All rights reserved. Reprinted with permission.

Bilateral incisions in Colles' fascia are then made lateral to the bulbocavernosus muscle to allow for blunt finger dissection to the perineal membrane (Figure 48.3). This finger dissection is medial to the ischial arch where the crura of the penis can often be felt, and lateral to the bulbocavernosus muscle. The amount of finger dissection should be kept to a minimum and should open a space large enough to safely allow for the passage of the Stamey needle from the suprapubic incision. Minimizing the blunt dissection at this point can significantly decrease problems with postoperative pain and numbness as this likely limits damage to terminal sensory nerve fibers in the region.

A four hole, 60°, extra long Stamey needle is then passed retropubically from the edges of the suprapubic incision lateral to the vesical neck and urethra. The needle is passed using tactile sensation against the under-surface of the symphysis to avoid perforation of the anterior bladder wall. The needle should exit anteriorly through the perineal membrane in the space developed previously, at the top of the ischial-symphyseal arch, between the bulbocavernosus muscle and the ischial bone (Figures 48.4 and 48.5). A flexible cystoscope is introduced to rule out perforation of the urethra or bladder. If perforation is seen, the Stamey needle is rerouted and passed again, often under cystoscopic guidance. Completion of the procedure after a urethral or bladder perforation has not increased our complication rate, but the appropriateness of procedure continuance should be at the surgeon's discretion.

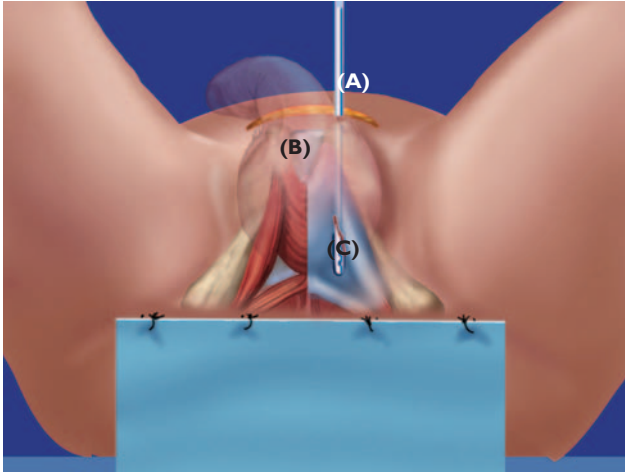


Figure 48.4 The Stamey needle (A) courses retropubically from the suprapubic incision (B) through the perineal membrane (C) lateral to the bulbocavernosus muscle and medial to the ischial arch. Cystoscopy should be performed with the needle in place to confirm the urethra and bladder have not been perforated. This maneuver is performed bilaterally. Courtesy of the American College of Surgeons. Cine-Med Inc © Copyright 2004. All rights reserved. Reprinted with permission.

Sutures from one end of each of the three bolsters are passed through the eyes of the Stamey needle (Figure 48.6). Each eye emits both nylon sutures from one end of the bolster. The needle is then withdrawn into the suprapubic incision carrying six nylon suture ends (Figure 48.7). The procedure is then repeated on the other side (Figure 48.8). The three bolsters are placed in parallel over the bulbocavernosus muscle and the ends are tucked inside the ischial-symphyseal arch. To minimize bolster migration, we then fix the posterior/proximal most bolster to the bulbocavernosus muscle with absorbable suture. The paired sutures from each bolster are passed through the three holes of each Hewson ligament button. The Hewson ligament buttons are used to stabilize the sutures and secure them to the anterior rectus fascia (Figure 48.9).

Intraoperative urodynamics

Once the bolsters are in place, the bladder is filled through the suprapubic tube with approximately 250 ml of water. Using a 7 Fr dual channel urethral catheter, baseline values for abdominal leak point pressure are obtained during a Credé maneuver. The bladder is then emptied and the catheter is retracted in the urethra to obtain baseline urethral pressures. The bladder is then refilled and tension is placed on the sutures until leakage during a second Credé ceases. Using the

7 Fr catheter, pressure measurements are again obtained in the bladder and urethra with the sutures at a constant tension. We have found that urethral pressures less than 130 cmH₂O and a leak point pressure of more than 150 cmH₂O correlate with the best outcomes but these should not be considered physiologic pressures. When the suture tension is found to be satisfactory, they are tied and secured across the anterior rectus fascia. Urodynamics are again repeated to verify the correct tension and bolster placement. The sutures are then cut long to make future retightening procedures easier if needed (Figure 48.9). The urethral catheter is removed and the wounds are irrigated with antibiotic solution and closed in two layers.

Postoperative management

Patients are routinely discharged on postoperative day 1 with suprapubic drainage. A voiding trial begins on the 3rd postoperative day and postvoid residuals (PVR) are recorded by the patient. The suprapubic tube is removed when the PVR is less than 50 ml and oral antimicrobials are continued for 3 days after suprapubic tube removal.

Bone-anchored operation

The bone-anchored bulbourethral sling is a recently developed procedure similar in principle to the above operation, except the sling material, usually composed of a polypropylene mesh, is fixed to the bilateral descending rami of the pubic bone. Perineal exposure is similar, but the dissection is carried out more laterally to expose the bilateral pubic rami in which six titanium bone screws (three on each side) are placed with a bone drill (In-Vance® bone drill, American Medical Systems, Minnetonka, MN, USA) to secure the non-absorbable mesh across the bulbar urethra (Figure 48.10). Short-term success rates of the two procedures are similar, but long-term results from the bone-anchored operation have yet to be published (Table 48.1).

OUTCOMES

Complications

Short-term urinary retention is a risk after any procedure that aims to increase urethral outlet resistance; however, published rates are low (0–3%). Retention is

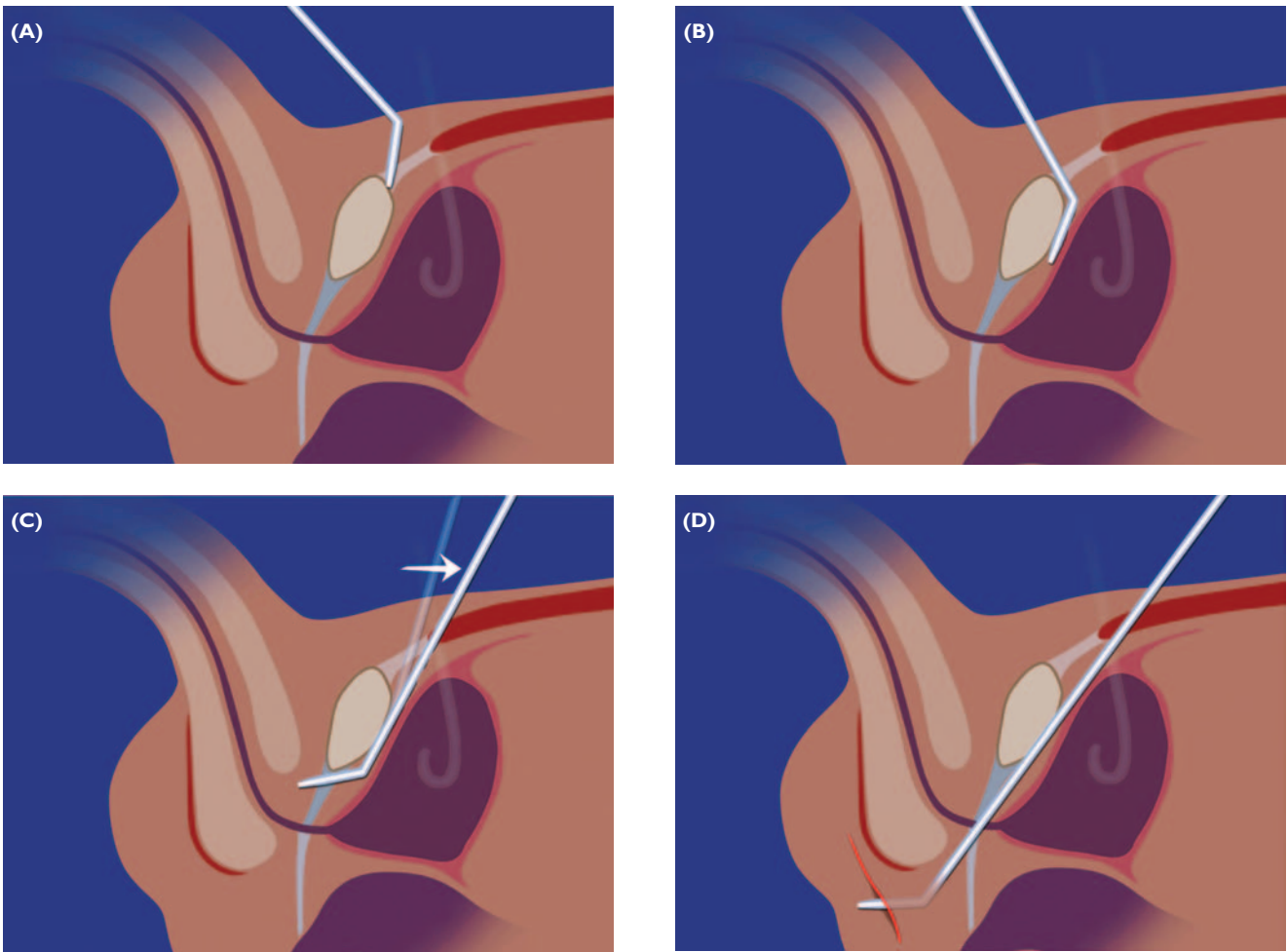


Figure 48.5 A lateral view showing the correct passage of the Stamey needle from the suprapubic incision (A) and under surface of the pubis using tactile sensation (B) through the perineal membrane (C) and out the perineal incision (D). These maneuvers helps to avoid bladder and urethral injury. Courtesy of the American College of Surgeons. Cine-Med Inc © Copyright 2004. All rights reserved. Reprinted with permission.

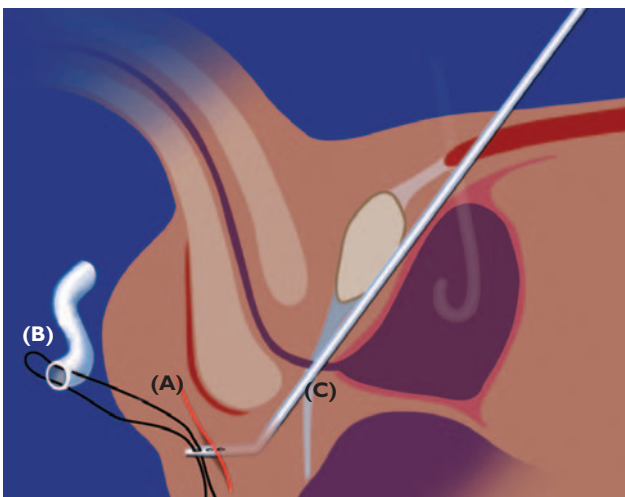


Figure 48.6 The polypropylene suture (A) has been placed through the bolster (B) with both ends of the suture placed through one eye of the Stamey needle (C). Courtesy of the American College of Surgeons. Cine-Med Inc © Copyright 2004. All rights reserved. Reprinted with permission.

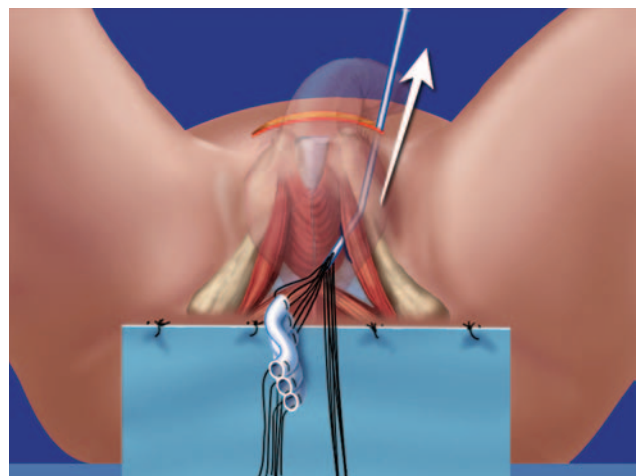


Figure 48.7 All polypropylene ties have been sutured to the bolsters and the ends placed through the eyes of the Stamey needle. The needle is then brought back through the suprapubic incision and the process is repeated on the contralateral side. Courtesy of the American College of Surgeons. Cine-Med Inc © Copyright 2004. All rights reserved. Reprinted with permission.

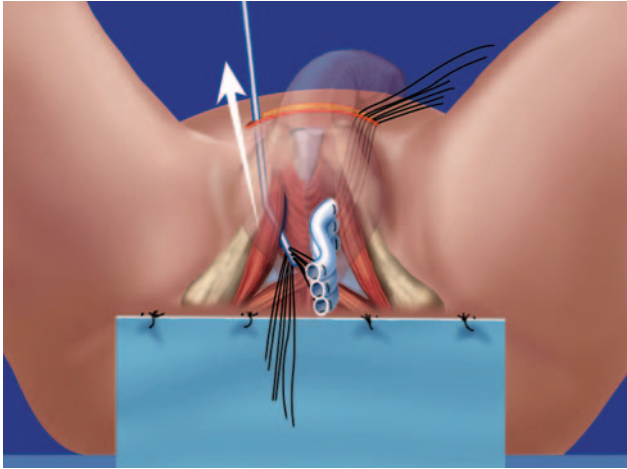


Figure 48.8 The Stamey needle has been passed on the contralateral side and the ends of the sutures have been placed through the needle eyes. Courtesy of the American College of Surgeons. Cine-Med Inc © Copyright 2004. All rights reserved. Reprinted with permission.

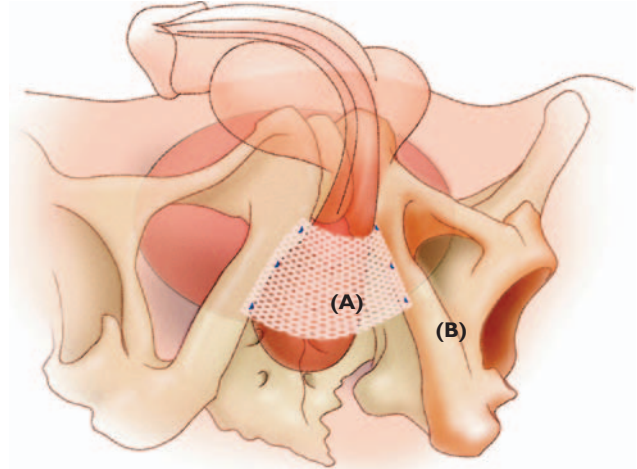


Figure 48.10 Bone-anchored operation. A polypropylene mesh (A) is shown anchored to the bilateral descending pubic rami (B). Courtesy of American Medical Systems, Inc. Minnetonka, Minnesota.

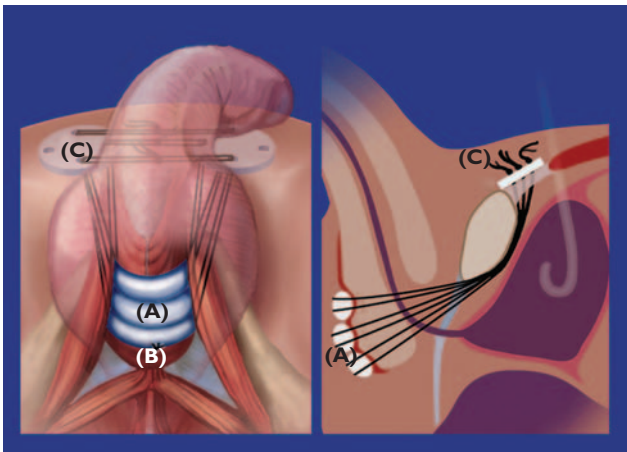


Figure 48.9 Completion of the bulbourethral sling procedure. The three bolsters have been placed in parallel and tucked inside the ischial-symphyseal arch (A). The most posterior bolster suture has been sutured to the bulbocavernosus muscle to avoid migration (B). The Hewson ligament buttons are resting on the anterior rectus fascia (C). Courtesy of the American College of Surgeons. Cine-Med Inc © Copyright 2004. All rights reserved. Reprinted with permission.

generally self limiting and managed with either prolonged suprapubic drainage or intermittent catheterization but in no series has it required sling removal. Postoperative urodynamics show an increase in urethral resistance during Valsalva, but normal urethral resting pressures and no evidence of obstructive voiding patterns, explaining the historically low rates of retention.⁹

If leakage recurs or persists postoperatively, a retightening procedure can be performed. The patient

is returned to the operating room, a suprapubic tube is placed and the previous suprapubic incision is opened. The buttons and sutures are identified, untied, and retied with increased tension using intra-operative urodynamics, as described previously, for guidance. Revision rates have decreased significantly with the introduction of the Hewson ligament buttons as these prevent suture migration; prior to their introduction, approximately 13% of patients underwent tightening procedures. This is generally an outpatient procedure and postoperative care is similar to the original surgery.

The overall infection rates range from 0 to 8% (Table 48.1) and in our series have decreased significantly with the use of Duraprep. Infection usually presents with perineal pain or discharge and should be treated with sling removal and broad spectrum antibiotics. A pelvic magnetic resonance imaging (MRI) scan can be performed if there is uncertainty in the diagnosis. We generally leave the perineal wound open to allow for irrigation and healing by secondary intention.

Urethral erosion rates range from 0 to 6% (Table 48.1), and the majority of cases in our series⁵ occurred in the early phases of sling implantation when appropriate urodynamic parameters for urethral resistance were unknown. By ensuring that the maximum urethral pressure is less than 130 cmH₂O and that there is sufficient bulbocavernosus muscle and overlying Colles' fascia between the sling and the urethra, erosion risk has been nearly eliminated. If encountered, sling material should be removed in its entirety and the urethra should be monitored for evidence of secondary urethral stricture disease.

Table 48.1 Bulbous urethral sling series comparison

	Number of men in series	Mean follow-up (months)	Dry (no pads) (%)	Improved (≤ 2 pads) (%)	Complications	Patient satisfaction (%)
Stern et al, 2005 ^{5*}	71	48	36	68	Infection 3%, erosion 5%, pain 19%, revision 20%	80
Castle et al, 2005 ^{6**}	38	18	16	40	Infection 8%, erosion 3%, pain 0%	NA
Rajpurkar et al, 2005 ^{7**}	46	24	37	74	Infection 0%, erosion 2%, pain 4%	70
Ullrich and Comiter, 2004 ^{8**}	36	25	67	92	Infection 0%, erosion 0%, pain NA	NA

*Rectus fascia anchored; **bone anchored.
NA, not available.

Potential complications specific to the bone-anchored operation include osteitis pubis and osteomyelitis. Osteitis pubis generally has a self-limiting course and is managed with anti-inflammatory drugs. Osteomyelitis of the pubic rami is rare, but requires broad spectrum antibiotics and sling removal.

Radiation to the pelvis is an independent risk factor for higher rates of urethral erosion and sling infection, and for a decrease in the overall effectiveness of the procedure. All patients undergoing sling procedures after radiation therapy should be made aware of these potential problems, but prior radiation should not be a contraindication in itself to the procedure, as many patients show lasting benefits.

Results

Outcomes from the four largest series with follow-up of more than 1 year are shown in Table 48.1. Success rates range from 40 to 92% and the percentage of men reported to be dry (wearing no pads) ranges from 16 to 67%. Complication rates are low in most series. All report higher success rates in non-radiated patients and those with less severe preoperative incontinence. Short- and intermediate-term results are similar to those of the AUS,¹⁰ but to date no randomized controlled studies comparing the two procedures have been performed.

CONCLUSIONS

The bulbourethral sling procedure is a safe and effective procedure for male incontinence secondary to

sphincter dysfunction. Along with the AUS, it should be viewed as permanent solution to deal with the problem of urethral sphincter incompetence after prostate surgery. The procedure is easy to perform with few complications and success rates similar to that of the AUS.

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49 One-stage hypospadias repairs

Douglas Canning and Andy Chang

INTRODUCTION

Hypospadias is the incomplete development of the male urethra resulting in the condition where the urethral meatus is located proximal to its normal location. The meatus in hypospadias may be located anywhere along the path between the perineum and the normal location in the glans. Common associated anomalies include incomplete foreskin with ventral preputial skin defect (in nearly all cases), ventral penile curvature (we no longer use the term chordee), and deficient corpus spongiosum. Only recently has research been focused on the genetic, hormonal, and environmental causes of hypospadias. Better understanding of the etiology of hypospadias may help in the surgical design and correction of the disease. As Culp and McRoberts stated, 'It is the inalienable right of every boy to be a pointer instead of a sitter by the time he starts school and to write his name legibly in the snow.' Thus, the goal of a practitioner of hypospadiology, 'the in-depth study of the art and science of the surgical correction of hypospadias',¹ as coined by Dr John W Duckett Jr, is to master the different techniques developed for the correction of this congenital defect and individualize them to each unique patient.

PRESURGICAL CONSIDERATIONS

Presentation

Typically, the child has a hooded prepuce, where the ventral shaft skin is lacking or poorly developed and the dorsal foreskin is present. Ventral glans curvature is also often present. Closer examination of the penis will reveal a more proximal located urethral meatus. Often it appears narrowed, but it is almost never so narrow as to impede voiding in the infant. Some boys have a variant of hypospadias, megameatus, where the foreskin is fully developed circumferentially and which is diagnosed only after circumcision.²

The location of the urethral orifice and degree of curvature should be noted. The meatus is always the most proximal, midline dimple along the urethral plate if multiple defects are seen along the ventral shaft of the penis.

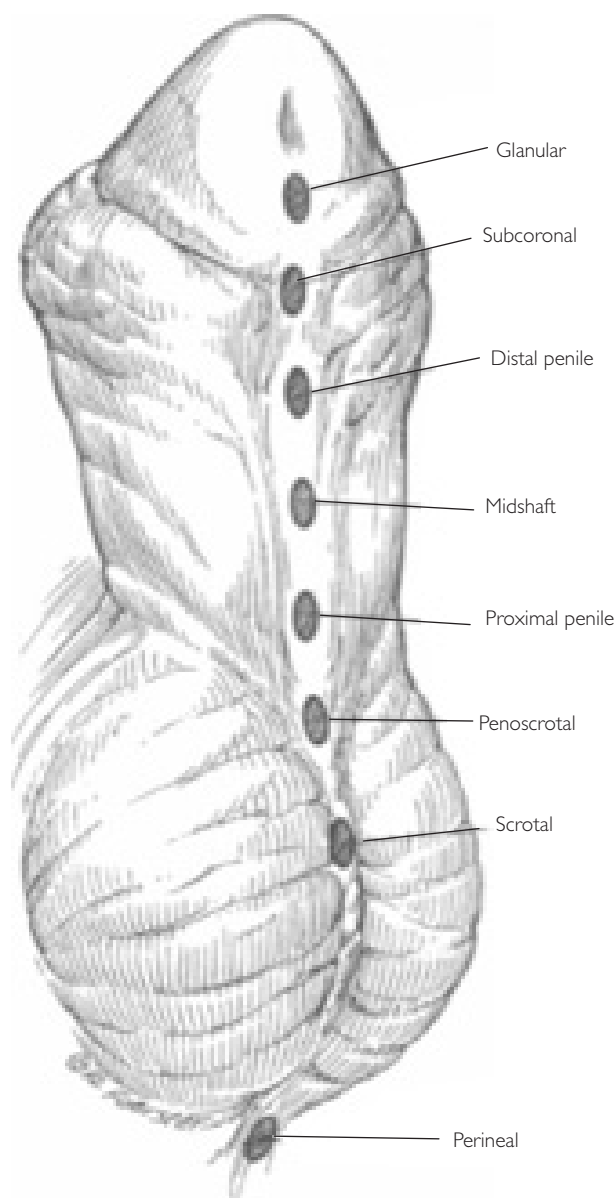


Figure 49.1 Classification of hypospadias based on anatomic location of the urethral meatus. Most hypospadias is distal, with the urethral meatus noted at or distal to the corona.

Meatal location can be anatomically classified (Figure 49.1), or generally as distal, middle, or proximal. Distal location is more common with 50–70% presenting with the urethral meatus at or distal to the corona, middle location occurs in 30%, and the rest are proximal.³

If hypospadias and cryptorchidism (undescended testis) are present, one must be alert for a disorder of sexual differentiation such as gonadal dysgenesis, true hermaphroditism, or congenital adrenal hyperplasia. If hypospadias and cryptorchidism coexist, the child should have blood drawn for a karyotype analysis and, if indicated, an evaluation for suspected disorder of sexual differentiation should be undertaken.

The penile length should be evaluated. If adequate surgical repair cannot be obtained because of a small glans, androgen stimulation can be considered. Koff believes that human chorionic gonadotropin (hCG) lengthens the penis relative to the location of the urethral meatus facilitating the repair.⁴

Timing of surgery

Although the American Academy of Pediatrics suggests the optimal age of male genital surgery to be between 6 and 12 months,⁵ we believe hypospadias can, and in many cases should, be performed earlier for the following reasons. Significant phallic growth occurs in most infants by 3 months of age, likely due to the postnatal testosterone surge that peaks around 2 months of life. Additionally, anesthesia can be safely administered for day surgery in term babies who are 4 weeks old and in premature babies after the 60th week of gestation.⁶ Furthermore, our surgery colleagues report nearly scarless wound healing after fetal surgery.^{7,8} Our experience has been that younger infants develop less scarring than older children after hypospadias repair. Finally, studies indicate that patients have more normalized psychologic development when hypospadias surgery is completed by 15 months of age.⁹ If initial repair results in fistula, or if a staged repair is needed, the secondary or tertiary repairs can still be completed before the child reaches age 15 months.

SURGICAL REPAIR

Considerations

Successful hypospadias repair needs to address and correct the following five areas:

- Orthoplasty (correction of curvature)
- Urethroplasty (reconstruction of the urethra to a normal distal location)
- Glanuloplasty (cosmetic reconstruction of the glans to a near normal appearance)

- Meatoplasty (construction of the urethral meatus to provide laminar flow and normal stream)
- Skin/tissue coverage (replacement of the penile shaft skin).

Instruments

Hypospadiology is plastic surgery. As such, good plastic surgery principles must be applied. Fine scissors, 0.5 mm toothed forceps, and Castroviejo needle holders are commonly used with fine absorbable sutures (6-0, 7-0, or 8-0) to delicately handle tissue and precisely place sutures with adequate but non-traumatic tissue purchase. We prefer the use of polyglycolic suture for construction of the neourethra and for subcuticular closure. Glanular stay sutures are used to minimize tissue handling during repair. Polydioxanone (PDS) suture is not recommended for urethral repair because of its extended absorption time and increased frequency of stricture.¹⁰

Hemostasis

Hemostasis is achieved with a variety of techniques. A tourniquet placed at the base of the penis and removed every 15–30 minutes alone or combined with needlepoint spot and bipolar electrocoagulation control is effective. The use of electrocautery is avoided as much as possible to minimize the potential for tissue injury. Instead, we prefer to inject 1:100 000 epinephrine in 1% lidocaine along the proposed incision line and in the glans deep to the urethral plate to provide adequate hemostasis while hydrodissecting a reliable plane between the skin and dartos fascia. With the use of epinephrine, we rarely need to use a tourniquet.

Skin incision and mobilization

The skin incision lines should be planned with care. The initial incision facilitates the urethroplasty as well as the ease, or difficulty, in accomplishing the repair. Because in most cases, the plan for the eventual repair is not possible before the initial dissection of the skin from the penile shaft, most of the repairs begin with an initial incision that does not compromise the ultimate choice of repair. Thus, all but one of the subsequent one-stage repairs begin in similar fashion.

A 5-0 polypropylene traction suture is first placed into the glans penis. A skin pen marks the incision



Figure 49.2 Example of initial incision lines. A 6–8 mm cuff is left proximal to the coronal sulcus starting at the dorsal midline and circumscribes the penis. Two parallel lines are drawn down the ventral shaft of the penis, incorporating the urethral plate between the lines. The meatus is outlined at the proximal edge. The ventral incision is then extended along the median, ventral aspect of the shaft caudally to the median raphe of the scrotum. Modified from reference 11, with permission.

line. The line is drawn on the dorsal aspect of the penis, 6–8 mm proximal to the corona, and continued ventrally to an area proximal to the meatus (Figure 49.2). The line is then extended further proximally to split the ventral shaft skin at the midline to the penoscrotal junction. Proximal extension of the ventral incision facilitates subsequent harvesting of onlay or dartos flap by allowing the penile shaft skin to flatten, resulting in better visibility of the pedicle of the flap and better separation of the pedicle and dorsal penile shaft skin. Next, the proposed incision line is infiltrated with a solution of 1:100 000

epinephrine in 1% lidocaine for hemostasis. The skin is cut and penis degloved to Buck's fascia. The dissection is begun ventrally from the urethral meatus to the penoscrotal junction and brought dorsally to the penopubic junction. To preserve the viability of the preputial flap, the dissection of the skin should avoid the intrinsic vascularity of the skin. The urethral meatus is then incised proximally until normal-appearing vascularized corpus spongiosum and normal bleeding from the native urethra are seen. An artificial erection is performed using normal saline and curvature is corrected as needed.

Lines along the boundary of the glans and the urethral plate are marked and infiltrated with 1 : 100 000 epinephrine in 1% lidocaine solution. Parallel incisions 10 mm wide are outlined, if feasible, along the urethral plate distally to the glans tip at the point where the flat ventral surface of the glans begins to curve around the meatal groove. The glans wings are developed along these lines, dissecting down to the level of the corpora cavernosa so that the spongiosum tissue can be laterally mobilized off the cavernosa for tension-free closure of the glans wings after the urethroplasty.

Correction of penile curvature

Penile curvature is best assessed after degloving of the penis. We find that preoperative ventral curvature is often overestimated, especially in children with distal hypospadias. After the penis is degloved, we find ventral curvature that requires correction in only 10% of distal hypospadias, but over 50% when the meatus is midshaft or more proximal. Artificial erection is performed by normal saline injection into the corpora cavernosa with a 25-gauge butterfly needle and rubber band occlusion at the base of the penis. One algorithm for management is shown in Figure 49.3.

If the curvature is less than 30°, dorsal plication usually corrects the problem. According to Baskin et al,¹³ the neurovascular bundles can be avoided by suture placement at the midline. However, we have usually placed the incisions at the 10 and 2 o'clock positions without complaints of sensation loss, even in adults. With either location, the region opposite the point of curvature is determined and Buck's fascia is incised. The wounds are closed as a Heineke-Mikulicz transverse closure of a vertical incision. We use three 6-0 PDS sutures placed on each side. Alternatively a single suture is placed into the intercorporeal septum. We then repeat the artificial erection to confirm straightening.

With curvature of greater than 30°, we mobilize the splayed corpus spongiosum off the underlying corpora cavernosa from the normal urethra proximally to its insertion in the glans wings distally. The artificial erection is repeated and any minor residual bending is straightened by dorsal plication.

When severe curvature still persists after corporal mobilization, the urethral plate is dissected off its junction with the normal urethra to release all remaining attachments to the corpora. If persistent curvature exists with repeat artificial erection, then the urethral plate is transected distally, usually at the corona. The urethral plate is then dissected proximally to the junction with the normal urethra. The urethral plate is replaced with a graft, necessitating a two-stage procedure, or a flap, which can be done in one or two stages.

Fewer than 5% of cases require transection of the urethral plate.¹² When significant corporeal disproportion results in persistent curvature that requires lengthening, multiple superficial transverse incisions along the corpora cavernosa are made until the penis is straight. Another approach is to make a single incision through the tunica albuginea at the point of maximal bending from 3 to 9 o'clock positions with grafting of dermis,^{14–16} tunica vaginalis,^{17,18} or single-ply small intestinal submucosa (SIS)^{19,20} to the defect. In general, we have avoided use of a ventral graft, and have been satisfied with our results.

Urethroplasty

The skilled hypospadiologist has an armamentarium of techniques to choose from in reconstructing the urethra. Historically, the decision was based on location of the hypospadiac meatus, distal or proximal. However, we believe the more important determination is the adequacy of the urethral plate. Furthermore, the glans size, degree of curvature, meatal location, and the quality of the foreskin also influence the choice of repair. Several one-stage approaches can give similarly good results if the urethral plate can be preserved. However, a one-stage repair after transection of the urethral plate can only be accomplished with a Duckett transverse island tube.

The hypospadiologist must be skilled in the numerous techniques available and have a fundamental knowledge of the principles required for successful outcome. Each repair has its advantages and disadvantages. No one repair fits each situation. Because failed hypospadias repairs progressively reduce the volume of healthy tissue available for reconstruction, careful planning to choose the correct surgery for each boy is important and helps ensure a successful, durable repair.

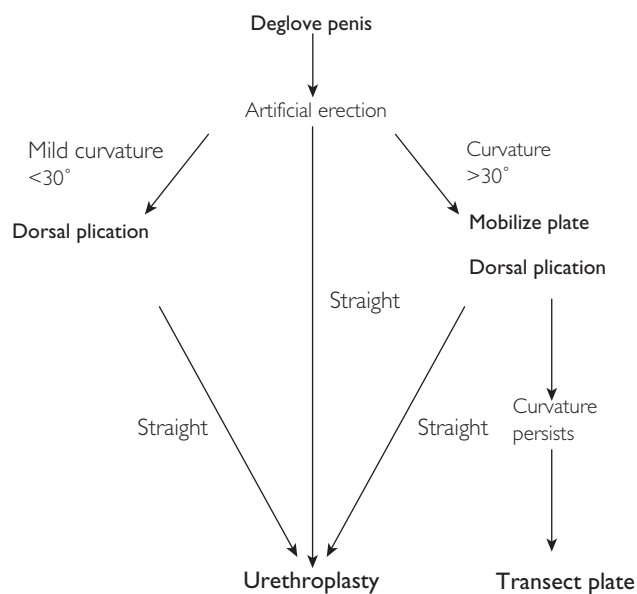


Figure 49.3 Algorithm for ventral penile curvature correction.¹¹

At the Children's Hospital of Philadelphia, we prefer the following single-stage repairs.

Meatal advancement and glanuloplasty

The meatal advancement and glanuloplasty incorporation (MAGPI) offers reliable cosmesis and long-term success when applied to glanular and selected coronal hypospadias. With the advent of the tubularized incised plate (TIP) urethroplasty, we use the MAGPI less frequently. Urethral mobility (assessed by distal traction on the meatus with fine forceps), a rounded glans, and absence of curvature are prerequisites for successful use of the MAGPI to ensure good cosmesis and to avoid meatal regression.

A circumferential incision 6–8 mm proximal to the corona and proximal to the meatus is made (Figure 49.4A). Care is taken during dissection of the penile shaft skin ventrally over the corpus spongiosum to avoid urethral injury. If injury occurs, the MAGPI repair will need to be abandoned in favor of a more extensive repair. A longitudinal incision from the dorsal distal edge of the meatus is carried to the distal glans groove transecting the transverse bridge of the tissue that is often present (Figure 49.4B). The incised tissue edges are approximated in a Heineke-Mikulicz fashion with 7-0 absorbable suture to advance the meatus distally (Figure 49.4C). The

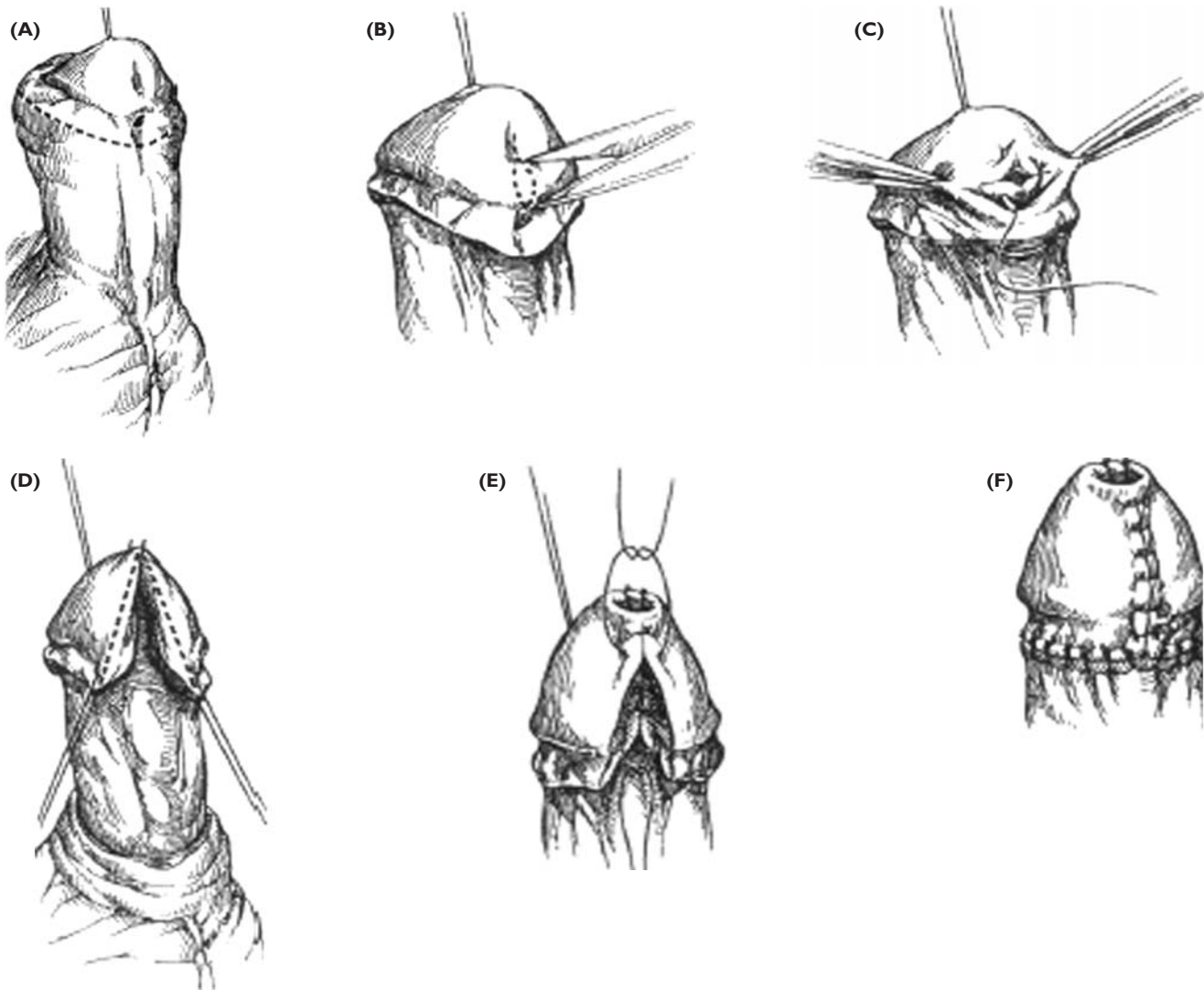


Figure 49.4 Meatoplasty and glanuloplasty repair (MAGPI). (A) Circumferential incision 5 cm below the corona. (B) Transverse bridge of tissue distal to the meatus is sharply incised. (C) A Heinek-Mikulicz closure opens and advances the meatus. (D) Ventral meatal edge is pulled distally and the exposed glans edges are trimmed and approximated. (E) Glanuloplasty is performed with subepithelial sutures to leave a rounded, conical glans. (F) Dorsal skin is transferred ventrally, excess skin is excised and no catheter is left in place.³⁶

medial edge of the ventral meatus is pulled distally and the exposed glans edges are trimmed to leave the glans with a cosmetically appealing, rounded appearance (Figure 49.4D). The dorsal hooded foreskin is trimmed in the midline to allow adequate ventral skin transfer, and the skin is approximated to the glans cuff with absorbable, subcuticular sutures to complete the repair (Figure 49.4E and F).

Tubularized incised plate – Snodgrass repair

Since Snodgrass introduced the TIP urethroplasty in 1994,²¹ it has gained in popularity and supplanted most other techniques. Initially used for distal

hypospadias, the TIP repair has now been successfully used for midshaft and proximal hypospadias. This technique can be utilized after curvature is corrected, if present, and the urethral plate is preserved. The cosmetic appearance of the repair is superb and the simplicity of the technique has led to its widespread use throughout the world.

Once the surgeon determines the feasibility of a TIP repair, the skin incisions and glanular wings are developed as described above (Figure 49.5). However, for a patient who desires a foreskin reconstruction, the skin incision extends from the corners of the dorsal preputial hood to 2 mm proximal to the meatus (Figure 49.6).¹¹

The midline incision of the urethral plate is an important step. The surgeon and assistant each grasp the lateral

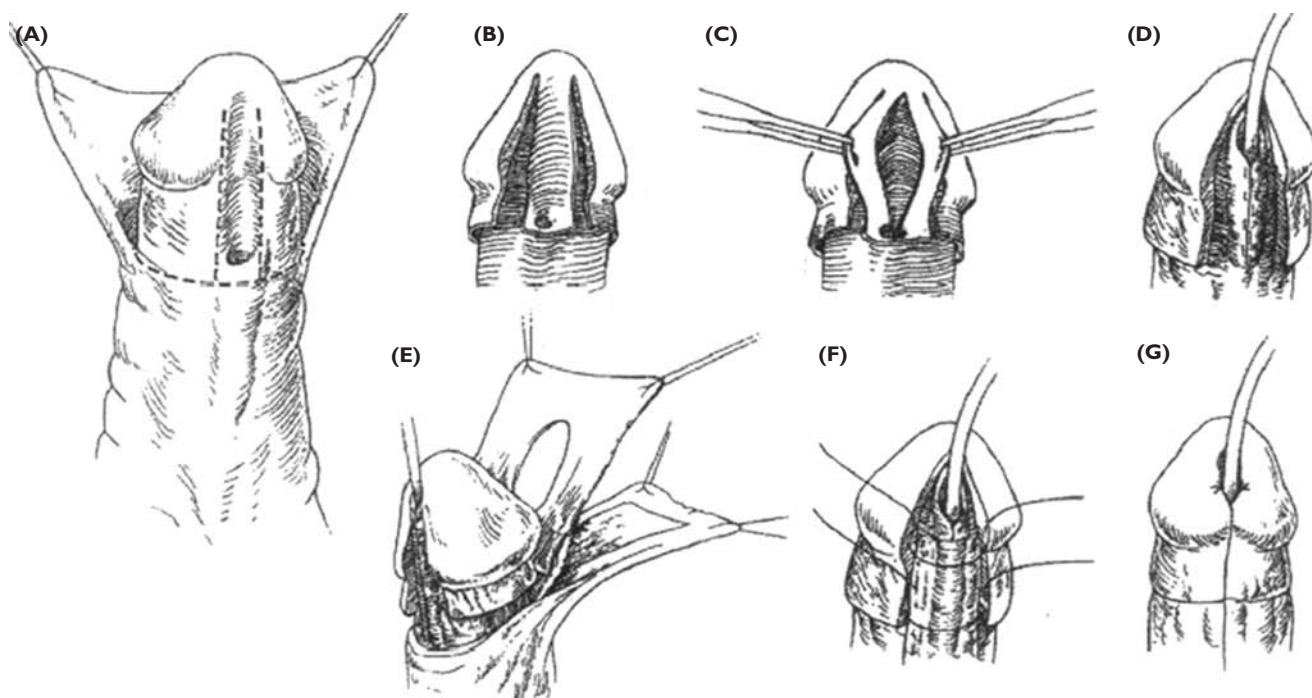


Figure 49.5 Tubularized incised plate urethroplasty. (A) Circumscising incision along dashed lines to deglove penis. (B) Glans wings mobilized laterally off the corpora cavernosa and separated from the urethral plate. (C) Longitudinal incision in the midline of the urethral plate. The incision widens the urethral plate. (D) Tubularization of urethral plate with a two-layer subepithelial approximation. (E) Dartos pedicle flap dissected off the inner preputial skin and transposed ventrally to provide an additional cover over the suture line. (F) Glans wings are approximated in the midline with subepithelial sutures. (G) Meatus sewn to glans at two positions and urethral stent secured in place.³⁷

margins of the urethral plate to provide adequate counter traction. A deep relaxing midline incision is made down to the surface of the corpora cavernosa, from within the native meatus to just proximal to the glanular apex. The urethral plate is closed over an 8 Fr feeding tube, using 7-0 polyglactin sutures placed in a subepithelial, simple interrupted fashion. The initial suture is placed at the neomeatus just distal to the middle of the glans, thereby creating an oval meatal appearance.

A dartos layer harvested from the prepuce, preserving the vascular pedicle provides additional coverage of the new repair. The dartos flap is brought from the dorsum to the ventrum, through a buttonhole in the pedicle. The overlying skin is separated and discarded. The dartos tissue is then used to cover the entire neourethra and secured with 7-0 polyglactin sutures to Buck's fascia.

Glanuloplasty is performed (see below for more details) and the shaft skin is closed with 7-0 polyglactin sutures in a subcuticular fashion for a circumcised repair. If the foreskin is to be reconstructed, the inner prepuce is first closed with interrupted 7-0 sutures and the subcutaneous dartos layer is then approximated. Finally, the outer skin is reapproximated for a three

layer closure. Urine is diverted with a 6 Fr Kendall stent and sandwich dressing is applied.

Onlay island flap

The circumscising incisions are made and the penis degloved in the usual fashion. However, unlike the TIP repair, the urethral plate need not be more than 2 mm wide prior to the onlay transfer.

An artificial erection is obtained with injection of normal saline. Ventral penile curvature is corrected as described above. The onlay island flap technique is continued if the urethral plate is preserved after any necessary penile curvature correction.

The flaps on the inner preputial skin surface are marked by 5-0 polypropylene stay sutures (Figure 49.2). The sutures are placed to accentuate the fold of tissue between the inner and outer prepuce. The initial incision is made just beneath the skin at the junction between the inner and outer preputial faces of foreskin, which sharply divides an 8–10 mm segment of the epithelium. To facilitate the flap harvest, the shaft skin

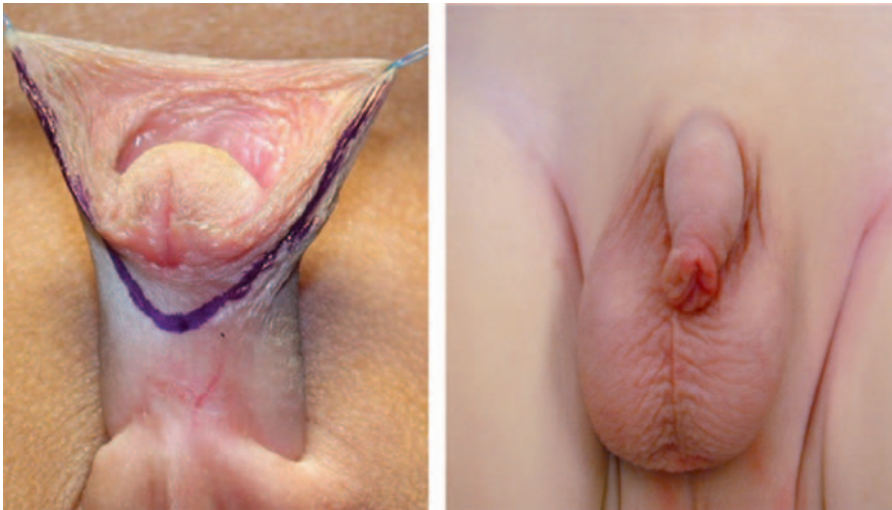


Figure 49.6 Skin incision to preserve the foreskin during a hypospadias repair. At the corner where the inner and outer prepuce meet, stay sutures are placed. An incision is made ventrally to 2 mm proximal to the meatus from each of the stay sutures. Effectively, the incision will be shaped like a 'V'. 'The penis is degloved ventrally to normal dartos tissues. During skin closure after urethroplasty the inner layer, intervening dartos, and outer layers are separately approximated'.¹¹

is flattened to establish the plane between the blood supply to the flap and the penile shaft skin.

The dissection of the vascular pedicle begins at the midshaft where it is usually easier to separate it from the blood supply to the dorsal penile shaft skin. The approach for flap harvest easily identifies the proper plane and ensures preservation of blood supply to the flap. Splitting of the ventral skin, completed during the initial circumcising skin incision, releases the base of the dorsal vascular pedicle and allows for wider mobilization of the preputial foreskin for flap isolation. The flap is then rotated ventrally, or, more commonly, transferred by creating a window in the vascular mesentery through which the glans is passed, and then tapered proximally and distally (Figure 49.7). To avoid turbulent voiding that may contribute to fistula and diverticulum formation, we aggressively trim the proximal flap to a wedge shape, providing a consistent caliber of tube as the neourethra meets the spatulated native urethra. The combined width of the preserved plate and the flap should be about 10 mm and no wider at the anastomosis than at the urethral meatus.

Experience has shown that too wide a neourethra may lead to kinking or diverticulum formation. The appropriately designed flap is sutured into place using lubricated interrupted 7-0 polyglactic suture at the proximal meatus and then in an interrupted subepithelial fashion along the lateral edges of the plate (Figure 49.7). An 8 Fr feeding tube is placed down the neourethra, once completed, to serve as a spacer to ensure an adequately sized glanuloplasty. After the glanuloplasty is completed in the usual manner, the 8 Fr feeding tube is replaced by a 6 Fr Kendall stent and secured with a 5-0 polypropylene suture. The dorsal

preputial skin is split in the midline and rotated ventrally to afford adequate circumferential skin coverage.

Transverse preputial island flap

(Figures 49.8 to 49.9) In the transverse preputial island flap (TPIF) technique, as with the other techniques, the skin incisions are made, the penis degloved, and an artificial erection is performed. If the penile curvature is severe, the urethral plate is transected and dissected off the corporeal tissue until the tethering is released. The ventral dissection of the urethral plate sometimes results in a relatively distal urethra displaced to the penoscrotal junction or even to the perineum. The glans is incised deeply in the midline and excess epithelium is trimmed. Appropriate-length dorsal longitudinal incisions are made off the midline and closed horizontally to correct ventral penile curvature. The artificial erection is then repeated to ensure penile curvature correction.

The inner prepuce is then harvested from the redundant dorsal prepuce and buttonholed to transpose the flap ventrally. The native urethral meatus is fixed to the corpora cavernosa with fine absorbable monofilament sutures. Previously, the neourethra was rolled and constructed over a tube prior to suturing the proximal end to the native urethral meatus.²² The technique has now been modified by first anchoring one side of the flap longitudinally to the ventral surface of the corpora cavernosa just off the midline using 7-0 polyglactin sutures. The anchoring begins at the posterior wall of the native urethra and proceeds distally to the proposed location of the neomeatus in the glans. This maneuver creates a new

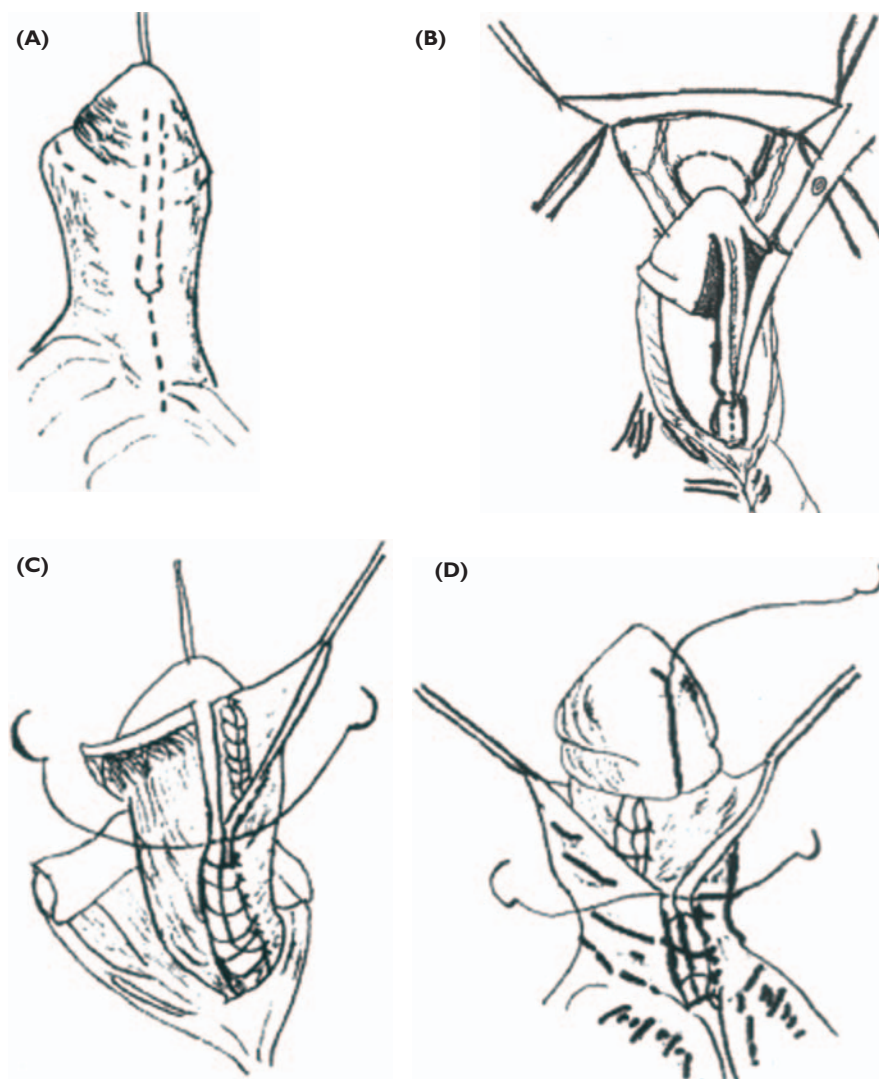


Figure 49.7 Onlay island flap repair. (A) Initiation of repair with incision lines and glanular holding stitch depicted. (B) Glanular wings created, as well as incision of skin made, including the ventral incision along the ventral shaft down to the penoscrotal junction. The thinned out urethra is being cut back to healthy, well supported urethra. The preputial flap is harvested. (C) The flap had been brought around to the ventrum through a button hole in the mesentery and sutured onto the urethral plate. (D) Skin closure. From reference 23, with permission. This article was published in the *Urologic Clinics of North America*, Volume 31, Issue 3, A. Shukla, R. Patel, D. Canning. Hypospadias. Pages 445–460. Copyright Elsevier, 2003.

urethral plate of inner preputial skin, which no longer binds the ventral corpora. The anchored medial edge of the tube allows the opposite end of the flap to flatten, to facilitate the construction of an appropriately sized neourethra. The tube must be narrowed substantially at the proximal anastomosis between the new and spatulated native urethra to align the skin edges and to construct a tube of ideal caliber without a diverticulum at the distal extent of the native urethra. An 8Fr feeding tube is used as a template to gauge urethral lumen as the closure proceeds.

To construct the neourethra, we place a second interrupted subcuticular suture line adjacent to the first suture line longitudinally along the ventral penile shaft. The urethral reconstruction continues distally to the glans penis. The glanuloplasty is completed over an 8Fr urethral stent with 6-0 absorbable monofilament horizontal mattress sutures, covering the distal edge of the tube and providing a cosmetically appealing appearance.

The 8Fr feeding tube is exchanged for a 6Fr Kendall stent for urinary diversion. The dorsal preputial skin is fashioned to provide adequate skin coverage.

Glanuloplasty

The glanuloplasty with medial rotation of mobilized glans wings is achieved with horizontal mattress 6-0 polyglyconate sutures placed parallel to the cut edge of the glans. The first stitch is placed at the location of the ventral aspect of the neomeatus, getting good purchase on the glanular wing tissue. The suture is then anchored to the distal neourethra before it is placed into the other glans wing. Two or three more horizontal mattress sutures can be placed to complete the glanuloplasty. Then, 7-0 polyglactin subepithelial sutures are placed proximal to the corona to anastomose the subcoronal skin collar.

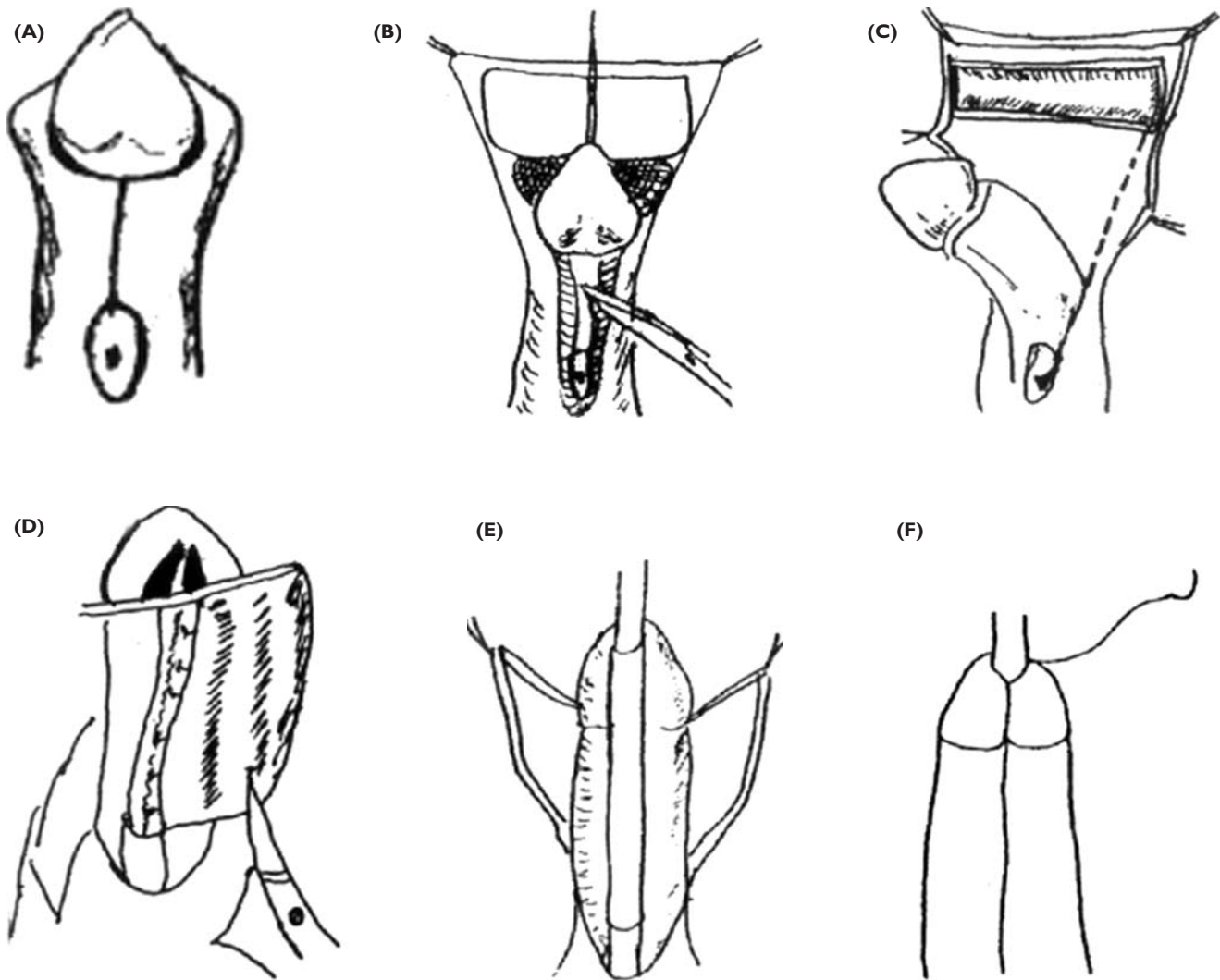


Figure 49.8 Transverse preputial island flap repair. (A) The incisions lines are demarcated. (B) After artificial erection had determined the need for transection of the urethral plate, it is excised from the glans all the way to the meatus proximally. (C) The preputial flap is harvested. Care is taken not to transect the vascular pedicle supplying the preputial flap. A button hole is created in the mesentery at the base and the flap is transferred to the ventrum. (D) One edge of the flap is anchored to corpora cavernosum just off midline along the length of the shaft. (E) The neourethra is rolled over an 8Fr feeding tube using interrupted, subcuticular 7-0 polyglactin sutures. (F) Glanuloplasty and skin coverage complete the repair. From reference 23, with permission. This article was published in the *Urologic Clinics of North America*, Volume 31, Issue 3, A. Shukla, R. Patel, D. Canning. Hypospadias. Pages 445–460. Copyright Elsevier, 2003.

Meatoplasty

The ideal appearance of the meatus is a slit-like configuration at the tip of the glans. This can be achieved by not tubularizing the distal half of the glans penis, leaving an oval meatus. With the glans wing closure, an appealing slit-like cosmetic outcome can be obtained.

Skin closure

In the US, hypospadias repair has traditionally included circumcision. In other countries as well as certain ethnic

groups in America, foreskin reconstruction is preferred. Thus, whenever possible, hypospadiologists should offer families the outcome that they desire. The foreskin can be reconstructed using the TIP repair. The main difference compared with repairs with circumcision is the initial skin incision does not extend circumferentially, but from the dorsal corner of the hooded prepuce ventrally under the meatus (see above section on TIP). Secondary phimosis is uncommon, and the fistula rate has not been increased despite the lack of dorsal dartos for a barrier layer.^{24–26}

Suture tracks or sinuses have occurred in as many as 40% of patients after hypospadias repair when stitches

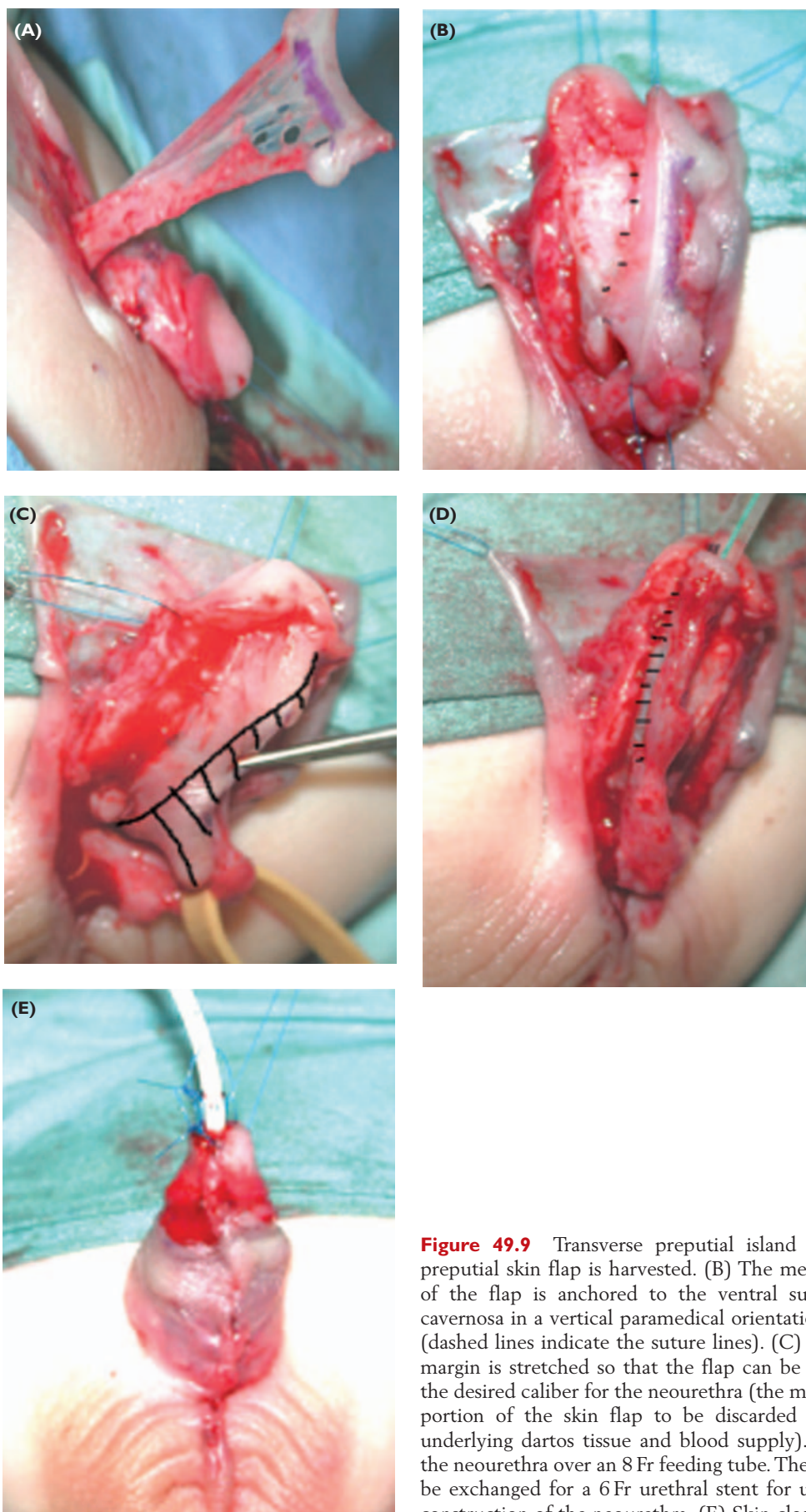


Figure 49.9 Transverse preputial island flap repair. (A) The preputial skin flap is harvested. (B) The medial, proximal margin of the flap is anchored to the ventral surface of the corpora cavernosa in a vertical paramedical orientation, either left or right (dashed lines indicate the suture lines). (C) The contralateral flap margin is stretched so that the flap can be accurately tailored to the desired caliber for the neourethra (the marked area depicts the portion of the skin flap to be discarded while preserving the underlying dartos tissue and blood supply). (D) Construction of the neourethra over an 8 Fr feeding tube. The 8 Fr feeding tube will be exchanged for a 6 Fr urethral stent for urinary diversion after construction of the neourethra. (E) Skin closure.¹¹

have been placed through the epithelium.²⁷ These may not appear for as long as 1 year after surgery. Thus, subepithelial stitches to minimize suture tracks are strongly advised. However, suture sinuses can still occur despite this technique.

Dressing, urinary diversion, and postoperative care

An ideal posthypospadias repair dressing should provide adequate but pliable compression and be easily removed within 72 hours in most cases. Numerous variations in type and style of dressing have been proposed, whereas for some even no dressing at all is a viable alternative.²⁸ We continue to prefer the Duckett 'sandwich-type' dressing that compresses the penis against the lower abdominal wall by placing a Telfa pad (Tyco-Kendall Corporation, Mansfield, MA, USA) and a folded gauze sponge on top of the penis followed by a bio-occlusive dressing (Tegaderm 3M Healthcare, St Paul, MN, USA).

Most surgeons prefer urinary drainage with a catheter following proximal and midshaft hypospadias repairs, yet no study has proven its utility in distal repairs. A multi-center experience reported by Hakim et al revealed similar results for distal repairs with or without postoperative urethral catheterization.²⁹ We use a 6 Fr hydrophilic Kendall catheter placed through the neourethra and sutured to the glans with a prolene suture anchored to the inner aspect of the meatus to avoid scarring of the glans. Because the rate of urinary infection is no different between an open and closed system, we allow the open end of the Kendall tube to drain passively into the diaper usually for 2 to 2½ weeks and prescribe prophylactic antibiotics,³⁰ usually trimethoprim-sulfamethoxazole. This approach helps prevent inadvertent catheter removal and eliminates 'air-lock' in the drainage tubing. Furthermore, oxybutinin is prescribed for bladder spasms.

COMPLICATIONS OF HYPOSPADIAS REPAIR

Fistulae

Urethrocutaneous fistulae are the most common complication of hypospadias surgery. Several factors have been implicated in their occurrence, including apposing suture lines from neourethral and skin closure, distal obstruction from meatal stenosis or urethral stricture, turbulent urine flow, and locally impaired vascularity. Fistulae are usually apparent within the first few months after surgery, but can develop years

later. Some close spontaneously, but most will require surgical correction.

Barrier layers may be helpful in separating the overlying suture lines between skin and the neourethra. However, fistulae occurred in 21% of proximal repairs despite a dartos barrier flap in each case.³¹

When fistulae are present, the repair is deferred for at least 6 months after the initial hypospadias repair. This allows for postoperative edema and tissue inflammation to resolve. The fistula track can be excised with mobilization of the local tissue to provide for a dartos layer closer. The urethra is closed primarily, with a second dartos layer closer, with care not to overlap suture lines. The skin is then closed in a subcuticular fashion. A success rate of 90% can be achieved in small fistulae amenable to this type of repair.³² If the fistula is close to the coronal margin or close to the proximal glans, a more extensive repair should be undertaken. The distal urethra from the meatus to the fistula is opened. The hypospadias repair is then redone with closure of the neourethra, placement of a barrier dartos flap, and redo glanuloplasty. Urinary diversion via urethral stent is recommended for all redo glanuloplasties and optional for the proximal excisional repairs.

Meatal stenosis

Meatal stenosis may result from poor distal vascularity and wound contracture, technical errors in meatotomasty, or less commonly, from balanitis xerotica obliterans (BXO). The temptation is to suture the neourethra too far distally, not allowing for mild postoperative contraction, which can lead directly to stenosis. BXO is not common in the US likely secondary to the preference for circumcised repair. However, if the foreskin is reconstructed, BXO should be higher on the differential list if the typical white scar is visualized on the meatus.

Calibration should be done on a visually small meatus to accurately diagnose stenosis. Meatotomy is effective for distal stenosis. However, a redo glanuloplasty with deep urethral plate incision may be necessary. BXO may respond to topical steroids, but usually requires complete excision of the diseased tissue and use of buccal mucosal graft in the repair.³³

Urethral stricture

When the urinary stream is diminished or uroflowmetry low, a neourethral stricture is suspected. The diagnosis is made with cystoscopy and calibration. Short strictures discovered within a few months of hypospadias repair

can be managed with dilatation under anesthesia or direct vision internal urethrotomy with success rates of up to 50%.³⁴ When strictures are detected later, these minimal techniques have success rates of 16–21%.^{34,35} Strictures usually represent vascular compromise; open repair is recommended. Inlay of buccal mucosal graft along the dorsal aspect of the strictured urethra after the area is opened can be useful.

Diverticulum

Visible ballooning during voiding and postvoid dribbling represents diverticulum. Distal obstruction, turbulent flow, and creation of too large a neourethra can all be etiologies of a diverticulum. Surgical correction involves repair of distal obstruction, if present, and excision of redundant tissue to restore a normal urethral caliber. Recurrence is rare.

Dehiscence

Separation of the glans can result from infection, poor vascularity, or tension on the repair. Repair requires reanastomosis of healthy glanular wings in a tension-free manner.

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50 Complex hypospadias repair

Jonathan H Ross

INTRODUCTION

Hypospadias repair involves penile straightening (orthoplasty), urethroplasty, and subcutaneous and skin coverage. Patients with severe hypospadias, including patients with ambiguous genitalia assigned a male gender, present particular challenges in all these aspects. More complex cases tend to have more significant chordee and a smaller phallus. The urethral defect is by definition more severe and the urethral plate tissue is generally less robust. The small rounded glans with minimal cleft typical of these cases also makes a urethroplasty more challenging for these patients. Finally, the limited amount of penile skin limits the reconstructive options. Certain aspects of the repair in any given patient may be accomplished with the same approaches utilized for more distal forms of hypospadias, but generally more aggressive techniques are required for the severe cases.

PREOPERATIVE CONSIDERATIONS

Hypospadias is generally repaired at 6–12 months of age. Earlier repairs are avoided because anesthetic risk decreases significantly over the first 6 months of life. Repair beyond 1 year of age is discouraged because genital awareness increases the psychologic morbidity of the operation. Early repair is particularly important for patients with severe hypospadias. These cases are frequently complicated by fistulae or other issues that will require a second operation to correct. Since it is advisable to wait at least 6 months between repairs to allow for all inflammation to resolve and scarring to mature, a delay in the initial operation may lead to a second operation occurring when genital awareness has become a significant issue.

Preoperative androgen stimulation should be considered in patients with complex hypospadias. Several authors have shown that preoperative stimulation with human chorionic gonadotropin (hCG) or testosterone leads to a significant increase in penile size.^{1,2} This increase in size is associated with a relative movement of the urethral meatus distally and an apparent diminution in the degree of chordee presumably due to disproportionate growth of the straighter proximal

shaft. Preoperative treatment may also increase the vascularity of the skin and spongy tissue as well as the volume of skin available for the repair. Both topical and intramuscular routes have been utilized, but the intramuscular route seems more reliable. We employ 15–25 mg of testosterone 6 weeks preoperatively. A second dose may be administered 2 weeks prior to the repair. The testosterone surge is transient, but parents should be warned that in addition to penile growth, some fine pubic hairs may appear and an increase in aggressive behavior may be noted. While side-effects are minimal, hormonal manipulation should be used selectively and reserved for patients with severe hypospadias and a diminutive phallus, severe chordee, and/or a paucity of preputial skin.

Hypospadias may be considered one end of the spectrum of intersex disorders. When associated with an undescended testicle a complete intersex evaluation is appropriate. Even when severe hypospadias is an isolated finding, patients may have a significant enlargement of the prostatic utricle, sometimes referred to as a ‘vagina masculinus’. A voiding cystourethrogram and/or cystoscopy should be considered in patients with proximal hypospadias to assess the utricle. When large, the utricle may be a source of infections or other complications following repair of the hypospadias. Whether and when an enlarged utricle should be removed is unclear, but most are small and of little consequence. However, even a modestly enlarged utricle may make urethral catheterization difficult if the catheter preferentially enters the utricle. To avoid encountering this frustrating problem intraoperatively, an attempt to pass a urethral catheter should be performed prior to beginning reconstructive surgery. If the catheter is difficult to insert, then a wire can be placed cystoscopically into the bladder at the beginning of the procedure. A catheter may then be passed over the wire as needed during the operation and at its completion.

ORTHOPLASTY

The first step in all hypospadias repairs is to circumcise and deglove the penis. The urethroplasty should

be planned and marked off on the penis before circumcision so that the incision will not encroach on the urethral plate or flaps. Except in the most severe cases, the initial incision should be brought proximal to the hypospadiac meatus preserving the urethral plate. The success of hypospadias repairs is greater when the urethral plate is preserved and tubularized flaps or grafts thus avoided. It is difficult to predict before degloving which cases will require division of the plate to accomplish straightening and so the urethral plate should be given the benefit of the doubt and preserved. It is also advisable to pass a catheter into the urethra before making the initial incision. The distal urethra is often thin and the incision should be brought proximal to this section even if it means a significant ventral meatotomy through the thin portion will be required. During degloving the dissection should be carried as close to the urethra and spongy tissue as possible so that all abnormal 'chordee tissue' is separated from the shaft. This strategy also preserves maximum blood supply to the subsequent skin flaps. The degloving should be performed aggressively down to the suspensory ligament dorsally and down to or beyond the penoscrotal junction ventrally. Aggressive dissection to the bulbar urethra may further correct chordee and decrease the apparent severity of the hypospadias.³

Once the penis is completely degloved, an artificial erection is performed and the degree of residual curvature assessed. If the residual chordee is mild, then a dorsal plication can be undertaken. Two plications on either side of the dorsal vein can be employed for moderate chordee when the phallus is of good length. However, aggressive plication should be avoided in patients who already have a short phallus. Penile torsion can also be corrected by angling the plication to rotate the glans around as the plication is closed. For more significant degrees of chordee a ventral corporal graft should be considered (Figure 50.1). We have divided the urethral plate in these cases, though it is possible to perform ventral grafting by elevating the urethral plate off the corporal bodies rather than dividing it. To accomplish the procedure a transverse unhinging incision is made across the ventral corporal bodies at the level of greatest curvature. It is important that the incision extend 180° going around to the lateral edge of each corporal body. In the midline the septum should be incised immediately under the tunix superiorly and inferiorly allowing the transverse incision to release into an elliptical defect. A graft is then sewn over the defect with running absorbable suture. Tunica vaginalis may be utilized as shown in Figure 50.1.⁴ Other materials that

have been employed include dermal grafts and small intestine submucosa (SIS) (see Chapter 83 and Chapter 85).

URETHROPLASTY

For severe forms of hypospadias the decision must be made whether to attempt the repair in one or two stages. Proponents of one-stage repairs argue that even if the reoperation rate for complications is high, there will still be a significant number of children who require only one operation; whereas all patients undergoing a two-stage repair will, by definition, require at least two operations. Furthermore, the reoperation rate following two-stage repairs is significant so that it is not uncommon for three or more operations to result. The argument in favor of a two-stage repair is that it more safely preserves all native tissues. One-stage repairs generally require splitting the blood supply between flaps used for the urethroplasty and those used for the skin. In this approach there is a risk that complications will result from tissue loss. Repairing those complications can be difficult, frequently requiring the use of graft material. In two-stage repairs tissue loss is unlikely and complications tend to be minor and easily repaired with healthy surrounding tissue. In practice, the decision regarding a one- versus two-stage repair for proximal hypospadias is more an issue of when, rather than whether to apply each approach. The decision depends on the degree of hypospadias, the amount and quality of tissue available for flaps, the complexity of associated problems (such as severe chordee or penoscrotal transposition), and the experience of the surgeon with various one- and two-stage repairs. When appropriately employed, both approaches give a good cosmetic and functional result. Furthermore, with either approach to complex hypospadias a relatively high reoperation rate should be expected.

One-stage approaches employed for distal hypospadias repairs can sometimes be applied to more severe forms of hypospadias. The tubularized incised plate (TIP) repair may be applied very selectively in these cases.^{7,8} The narrow urethral plate and round glans lacking a cleft that are typical of proximal hypospadias may lead to a high incidence of meatal stenosis, meatal retrusion, and fistula in patients undergoing proximal TIP repairs. The TIP repair should probably be reserved for those with robust urethral plate tissue and a reasonable glans cleft. If the urethral plate can be conserved but is inadequate for a TIP repair, then a transverse island onlay is an excellent approach. When the

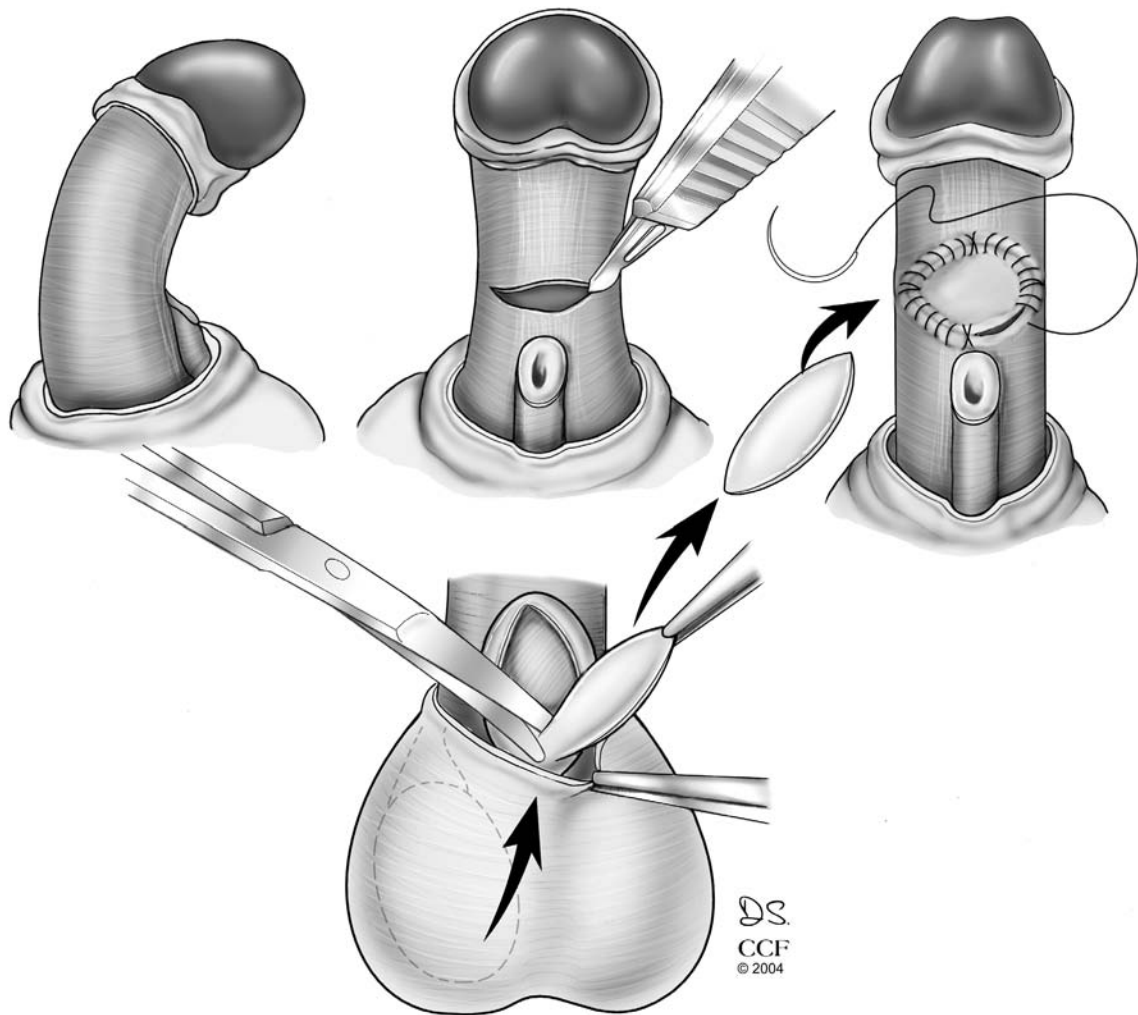


Figure 50.1 Ventral corporal graft with tunica vaginalis. A transverse incision is made in the corporal bodies at the level of greatest curvature and relaxed into an elliptical defect. The defect is closed with an ellipse of tunica vaginalis harvested from either testicle. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

urethral plate must be sacrificed to achieve orthoplasty, then a tubularized transverse island flap can often be employed. These approaches are described in Chapter 49. However, these last approaches require splitting the blood supply between the urethral and skin flaps. If the urethral plate can be preserved the double-onlay preputial flap may ameliorate concerns regarding tissue loss due to this division of blood supply.⁹ In this approach the inner preputial urethroplasty flap and the outer skin overlying it are mobilized on a single tissue pedicle reducing the possibility that the overlying skin will be lost. In the initial report, four of 18 patients required reoperation for minor complications that were easily corrected. Koyanagi et al described a one-stage technique for repairing severe hypospadias when the urethral plate must be divided.¹⁰ This approach

utilizes parametatal flaps extending onto the prepuce. Despite the rather long narrowly based flaps, this repair has been applied to all degrees of hypospadias with complication rates of 20–50%.¹¹

Two-stage repairs have been employed for correction of severe hypospadias for decades with complication rates ranging from 5 to 37%.^{7,12–14} They are particularly appropriate in patients with limited penile tissue or when there is particular concern regarding the compromise of tissue flap blood supply due to severe chordee, ambiguous genitalia, and/or penoscrotal transposition. At the first stage the chordee and penoscrotal transposition are corrected (Figures 50.2 and 50.3). The dorsal skin is brought around ventrally and fixed in place as a neourethral plate. If the glans is small it may be incised in the

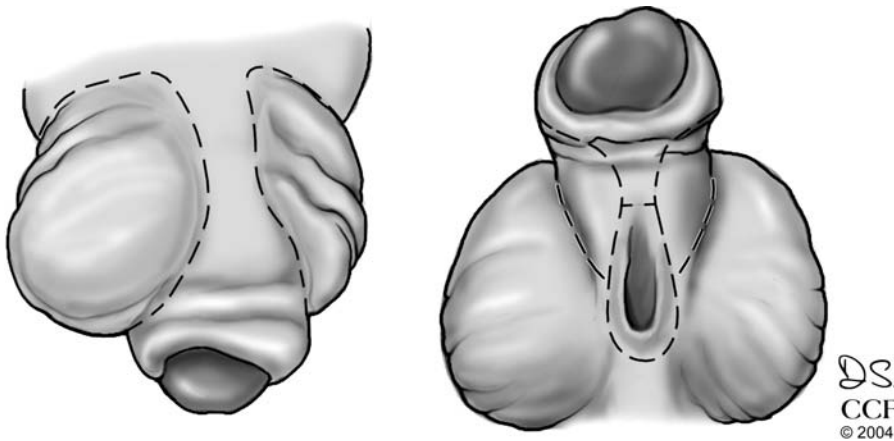


Figure 50.2 Initial incisions for two-stage repair in patient with severe hypospadias and penoscrotal transposition. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

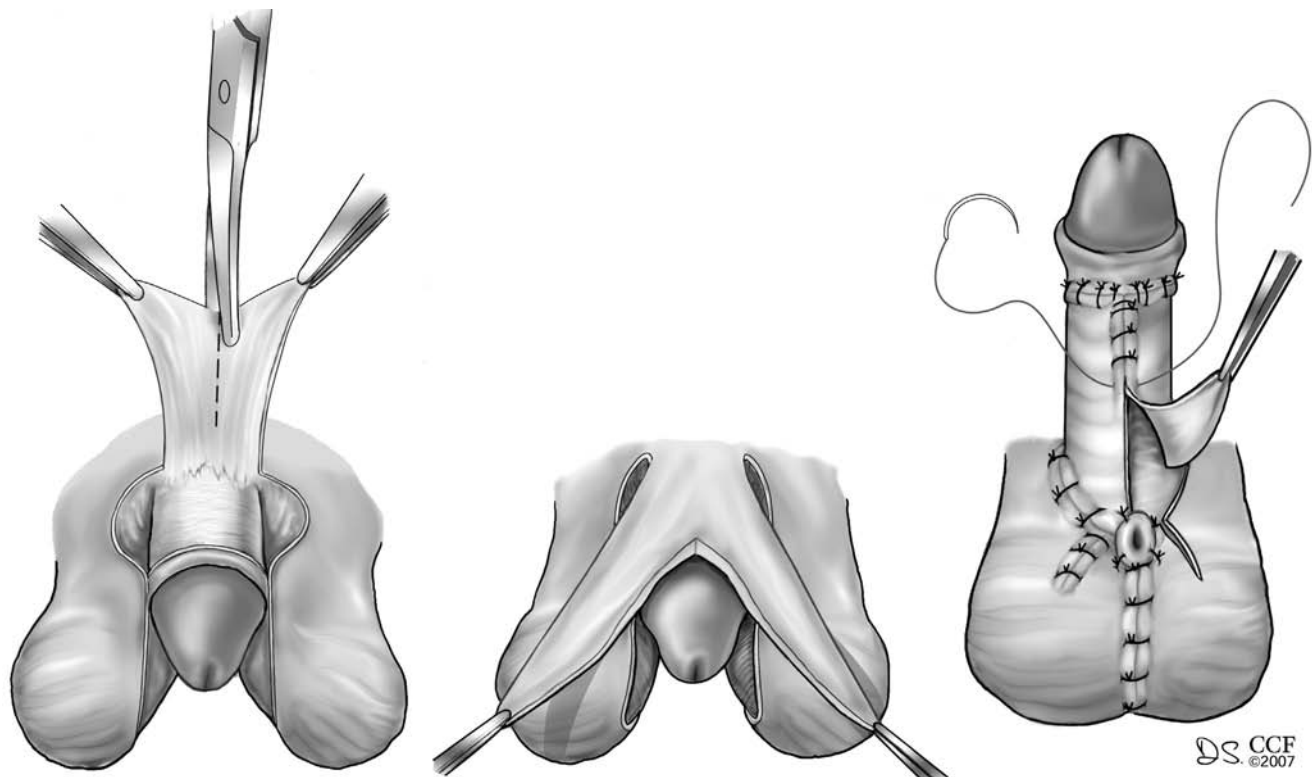


Figure 50.3 Completion of the first stage of a two-stage repair. The hemiscrota are dropped to a dependent position. A dorsal slit is performed and the flaps brought around to cover the ventrum of the penis creating a neourethral plate. If the glans is small, it may be incised longitudinally and the tips of the skin flaps placed in the defect to create the glanular neourethral plate (not shown). Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

midline and the skin flaps placed in the gap to widen the glans for tubularization at the second stage. Alternatively (as depicted in Figure 50.2) the ventral mucosal skirt and glans may be preserved at the first stage. In the second stage, a simple tubularizing urethroplasty is performed (Figure 50.4). If the glans was not incised at the first stage, then a longitudinal unhinging incision is made in the glanular urethral plate at this stage prior to tubularization.

Except in cases where the skin over the urethroplasty has been preserved (i.e. the double-onlay preputial flap) all urethroplasties should be covered with tissue prior to skin closure. In most cases a de-epithelialized skin flap can be employed.¹⁵ When available the subcutaneous tissue from dorsal hood flaps brought ventrally is an excellent source (Figure 50.5). Utilizing both flap tips, one applied distally and one folded to cover the ventral shaft, long urethroplasties can be covered. When inadequate

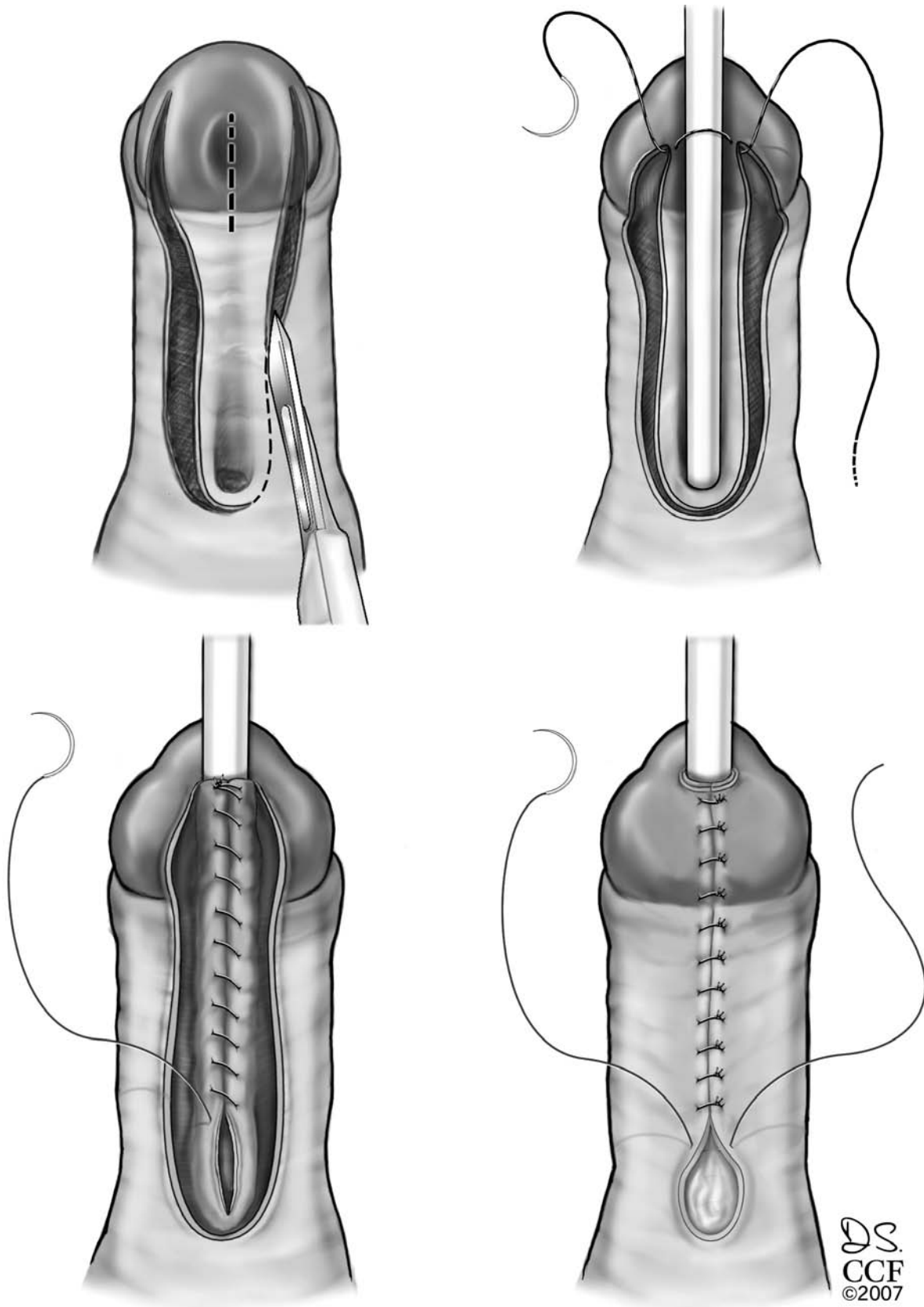


Figure 50.4 The second stage of a two-stage repair. The urethral plate is outlined and a longitudinal unincising incision is made in the native coronoglanular urethral plate (if it was left intact at the first stage). The urethra is then tubularized with running absorbable suture. It should be covered with local de-epithelialized skin flaps or a tunica vaginalis flap and then the skin is closed. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

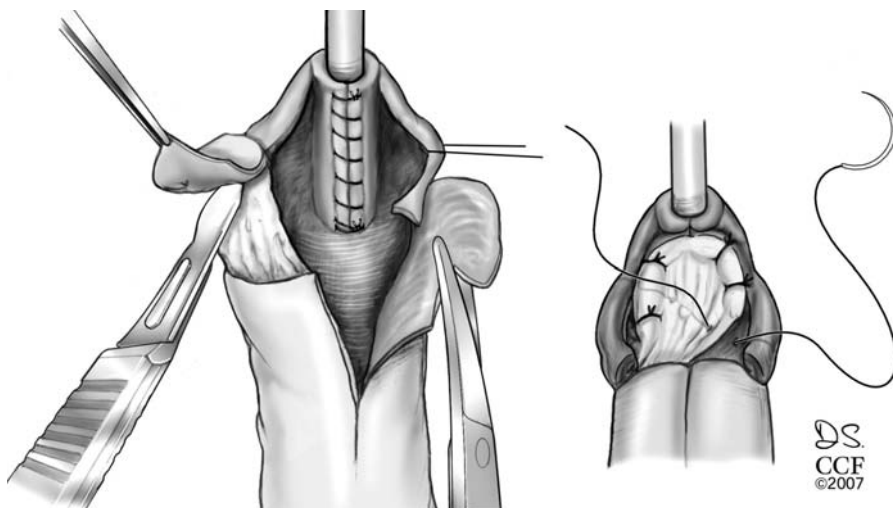


Figure 50.5 A de-epithelialized flap is created from the tip of the right half of the dorsal skin flap and placed over the urethroplasty (a distal hypospadias is shown). Both flaps may be used to cover longer defects following more proximal repairs. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

dorsal hood tissue is available (e.g. at the second stage of a two-stage repair) one edge of the skin to be used for the ventral skin closure can be de-epithelialized longitudinally. This tissue can then be draped over the repair and secured in place followed by skin edge approximation in a vest over pants technique. When there is no healthy skin available to create a subcutaneous flap, a tunica vaginalis flap may be employed. Through a mid-line scrotal extension of the incision, the testis is delivered into the operative field within the tunica vaginalis. A rectangular flap of tunica vaginalis based proximally is elevated and sewn over the urethroplasty. Often a long enough flap to cover the entire repair is possible, but care should be taken not to create tension that could lead to ventral tethering of the penis postoperatively. Following proximal hypospadias repairs a catheter is usually left indwelling for 7–14 days.

COMPLICATIONS

Not surprisingly, complications occur more commonly following repairs of proximal hypospadias than following distal repairs. The most common complications are urethrocutaneous fistula and meatal stenosis. Meatal stenosis can sometimes be managed with a simple meatotomy. However, the stricture will sometimes extend to the corona or distal shaft. In these cases the meatotomy must be carried aggressively down to healthy tissue. If this results in significant hypospadias, then a secondary repair should be undertaken. A meatal-based flap is usually the best approach. In cases of balanitis xerotica obliterans or very scarred distal tissue, a two-stage approach may be required. At the first stage an aggressive meatotomy is performed with or without excision of the scarred urethral plate. A

buccal mucosa graft is then placed dorsally. At the second stage a simple tubularization is undertaken.

The approach to a urethrocutaneous fistula depends on the size and location of the fistula as well as the quality of the surrounding tissues. For coronal fistulae with thin tissue between the fistula and meatus, the fistula should be opened to the meatus, recreating the hypospadias which can then be repaired, usually with a meatal-based flap. For proximal fistulae and coronal fistulae with thick surrounding tissue, a primary closure may be undertaken. The fistula is circumscribed and mobilized. The plane of dissection should be just under the epithelium of the fistula tract. The tract should be mobilized to the urethra and the surrounding tissue elevated off the urethra. The tract is then excised and the urethra closed with absorbable suture, in two layers if possible. The subcutaneous tissue and skin are closed in separate layers. Whenever possible, tissue should be interposed between the urethral and skin closures. Most often a de-epithelialized local skin flap can be generated. For proximal fistulae the incision may be extended proximally into the scrotal raphe and a flap of Dartos or tunica vaginalis can be brought up to cover the fistula. A catheter may be left indwelling for 3–10 days depending on the complexity of the repair.

Urethral strictures are uncommon and usually occur when tubularized flaps or grafts are employed in the initial repair. Short annular strictures can be managed with an internal urethrotomy with an anticipated success rate of approximately 50%.¹⁶ If an initial incision fails, repeat urethrotomies rarely succeed and will create additional scarring that will complicate an open repair. When internal urethrotomy fails or is inappropriate due to the length and quality of a stricture, then an open urethroplasty is indicated. Local non-hair-bearing skin flaps

should be used when available. Alternatively buccal grafts may be employed. The urethral plate should be preserved if at all possible as onlay grafts and flaps are more successful than ones that are tubularized.

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51 Urethral duplication and megalourethra

Michael Carr

URETHRAL DUPLICATION

Urethral duplications and megalourethras are rare congenital anomalies that lend themselves to case reports because of their unusual nature. Urethral duplications are seen in males and can be categorized as either sagittal or collateral. The former, where the channels occur one on top of another, is much more common. These duplications may be complete or incomplete with the accessory urethra more likely to be seen distally than proximally. Collateral duplications comprise urethras that lie side-by-side with. One classification scheme of urethral duplication was described by Effman et al.¹ The most prevalent duplication, type I, represents an incomplete duplication that ends blindly; it is usually asymptomatic and requires no treatment. Type IIA is a complete patent duplication with two meatuses. It is further subdivided into type IIA1, non-communicating urethras arising separately from the bladder, and type IIA2, where a second channel arises from the first. These have also been referred to as Y duplications. Type IIB is patent duplication with one meatus. Type III is duplication as a component of partial or complete caudal duplication (Figure 51.1).

Another classification described by Williams and Kenawi³ divided the sagittal duplications into four groups: epispadiac or hypospadiac, depending on the position of the accessory meatus; spindle urethra, where the urethra splits into two then reunites; and Y duplication, with a pre-anal or perineal accessory channel. The epispadiac and hypospadiac groups were further subdivided into complete (the two urethras leave the bladder separately and remain separate), incomplete (one channel divides distally), and abortive (a blind ending penile sinus).

Collateral duplications are either complete (with diphallus) or abortive (one urethral channel is occluded). Epispadiac or hypospadiac duplications can be considered dorsal or ventral duplications. In the dorsal or epispadiac variety, where an accessory meatus is positioned above a glanular meatus, the normal urethra is the ventrally positioned channel that usually ends in a normal meatus on the glans. The accessory (abnormal) channel is present on the shaft in an epispadiac position anywhere from the glans to

the base of the penis. These are often associated with an upward curve of the penis and, when complete, may cause incontinence. The foreskin may be unfused dorsally. The abnormal dorsal segment extends proximally beneath the symphysis pubis for a varying length. Many end blindly before reaching the bladder. If these abnormal urethras do reach the bladder, the patient usually is incontinent. Widening of the symphysis pubis may also be found. These findings suggest a relationship between this anomaly and the epispadias-exstrophy complex.^{4,5} Rare cases have been described in which this accessory channel never enters the bladder but continues along the ventral surface of the bladder joining the urachus. This suggests an abortive duplication of the bladder rather than the urethra. Since the normally positioned urethra has a normal bladder neck and sphincter mechanism, excision of the abnormal epispadiac urethra usually cures any incontinence affecting the patient. Significant penile chordee may also have to be repaired. Ventral duplications of the urethra or hypospadiac duplications are less clearly understood embryologically. They may be complete, with two separate urethras coming off the bladder. Other cases are incomplete with the urethra bifurcating somewhere distal to the bladder neck. Patients may have a hypospadiac meatus on the penile shaft. However, the most serious variation, the so-called Y duplication, occurs when the ventral meatus is present at the anterior anal margin. The dorsal penile urethra may be narrowed and inelastic, urine traverses preferentially through the peri-anal urethral opening, with the ventral urethra being considered the more normal urethra, because it traverses the sphincter complex.⁶ Alternatively, congenital posterior urethral perineal fistulae may represent a distinct subset of urethral duplication. The ventral urethra is less functional, is lined by transitional cell epithelium and should be excised by primary perineal excision (Figure 51.2).⁷

The embryologic etiology of all types of duplication is different. The epispadiac group is associated with the exstrophy-epispadias complex of abnormalities with some cases manifesting the bony malformations such as the widened symphysis. Hypospadiac urethral duplications may be related to failed closure of the

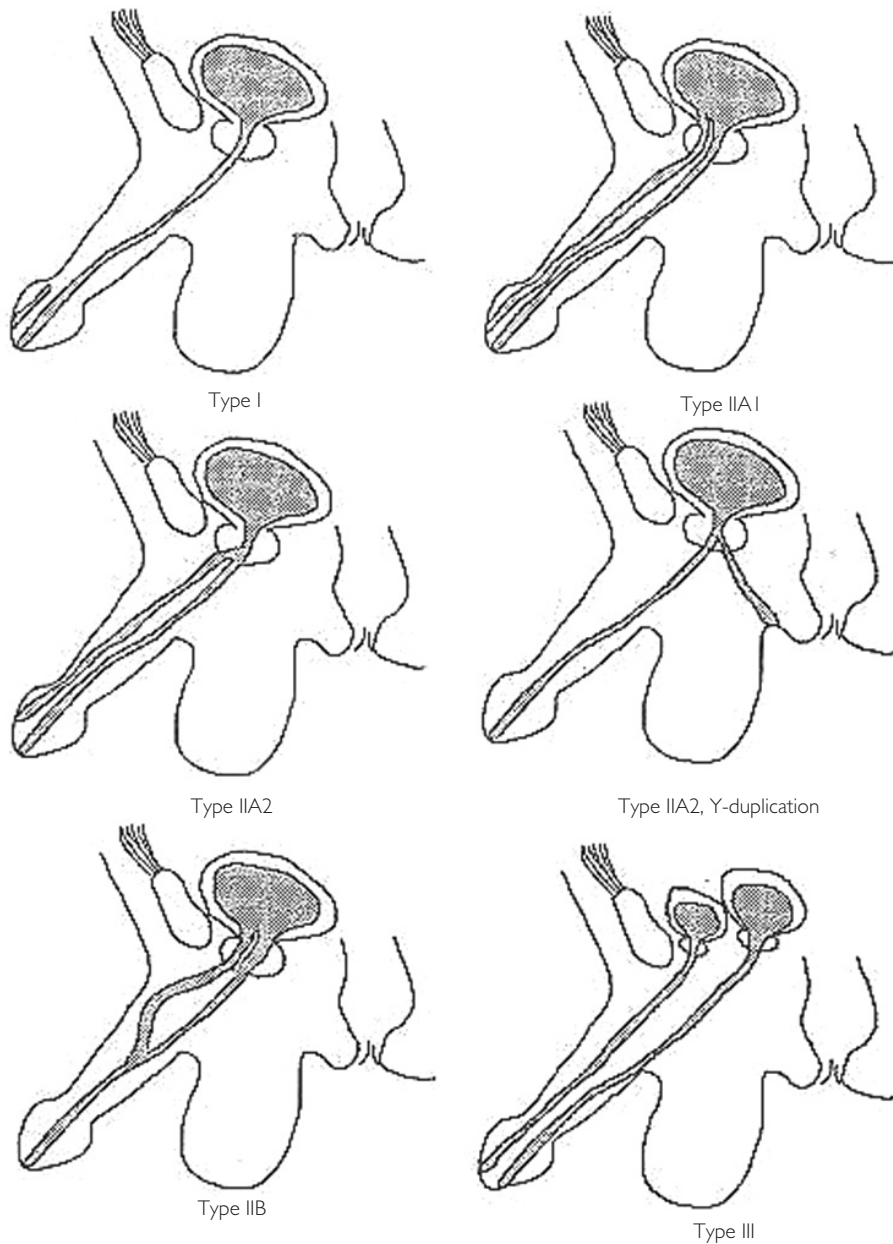


Figure 51.1 Classification of urethral duplications. From reference 2, with permission.

urethral folds.² Y duplications may be associated with a vascular accident at the time of formation of the urorectal septum.¹ Urethral duplications in females in the absence of bladder duplication are extremely rare.⁸

Management of urethral duplication depends on the anatomy of each particular anomaly. A voiding cystourethrogram will usually define the anatomy allowing preoperative planning for correction. Endoscopy at the time of reconstruction may be necessary to completely understand the lesion. If the presenting symptoms are a minor splitting of the urinary stream during voiding, repair may not be necessary. Such consideration is typically only appropriate for those patients

with both meatuses immediately adjacent to one another. A simple meatoplasty combining the two openings may rectify the problem. Divergence of the two openings will increase the complexity of the repair, especially if the dominant ventral meatus is very proximal. In this situation, the ventral perineal urethra must be mobilized away from the rectum to a more orthotopic location with the remainder of the urethral reconstruction via any number of urethroplasty techniques. An intact prepuce is certainly useful in this situation. Neonatal circumcision should not be undertaken if a urethral duplication anomaly is recognized. Buccal mucosa may be needed in patients who

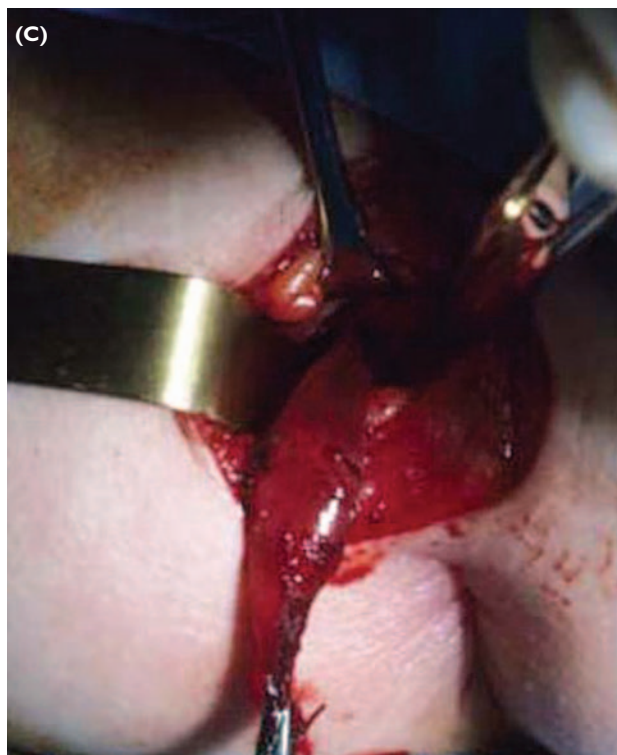
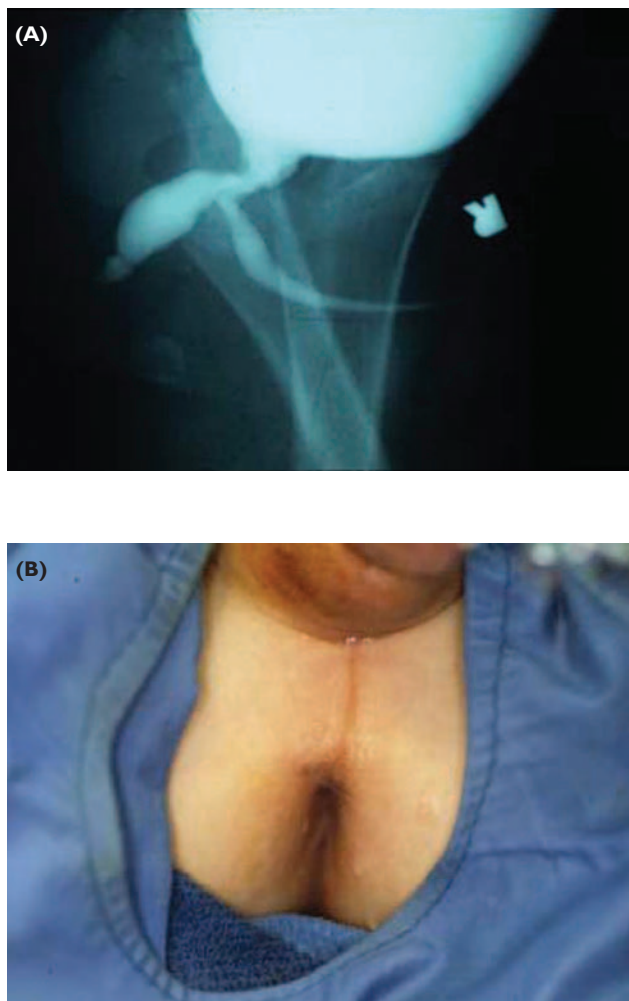


Figure 51.2 (A) Voiding cystourethrogram demonstrating type IIIA2 urethral duplication or Y duplication. (B) Evidence of posterior urethral perineal fistula. (C) Surgical resection by perineal approach.

have undergone prior circumcision or where the remaining prepuce does not provide adequate length for reconstruction. Additional surgical options include marsupialization of the normally positioned urethra, excising the fistula and repairing the perineal hypospadias at a later date; alternatively, a scrotal flap may be tubularized and anastomosed to the proximal portion of the fistula, thus creating a penoscrotal hypospadias that can be repaired as a second-stage procedure.^{9,10} A single-stage procedure may be performed in which the penile urethra is reconstructed as if it were a penoscrotal hypospadias with anastomosis of the proximal end to the larger of the duplicated channels. Finally, Passerini-Glazel et al¹¹ have described gradual serial dilatation of the dorsal urethra to render it useful for voiding. This is the same principle that has been employed in the atretic urethras that are seen sometimes in patients with the prune belly syndrome.

MEGALOURETHRA

This condition is a rare congenital anomaly characterized by abnormal dilatation of the pendulous urethra that is associated with abnormal development of the corpus spongiosum and occasionally with abnormal development of the corpora cavernosum. These anomalies were originally described by Nesbitt¹² in 1955 and then classified by Dorairajan,¹³ who divided the condition into scaphoid and fusiform varieties. The scaphoid form results from deficiency or absence of the ventral corpora spongiosum. The fusiform variety involves complete absence of both the corpora cavernosa and corpus spongiosum over the extent of the penile urethra so that the penis consists of a flabby elongated sac with a wall of mucosa and skin.¹⁴

The cause of megalourethra remains somewhat controversial with Stevens and Fortune¹⁵ postulating a

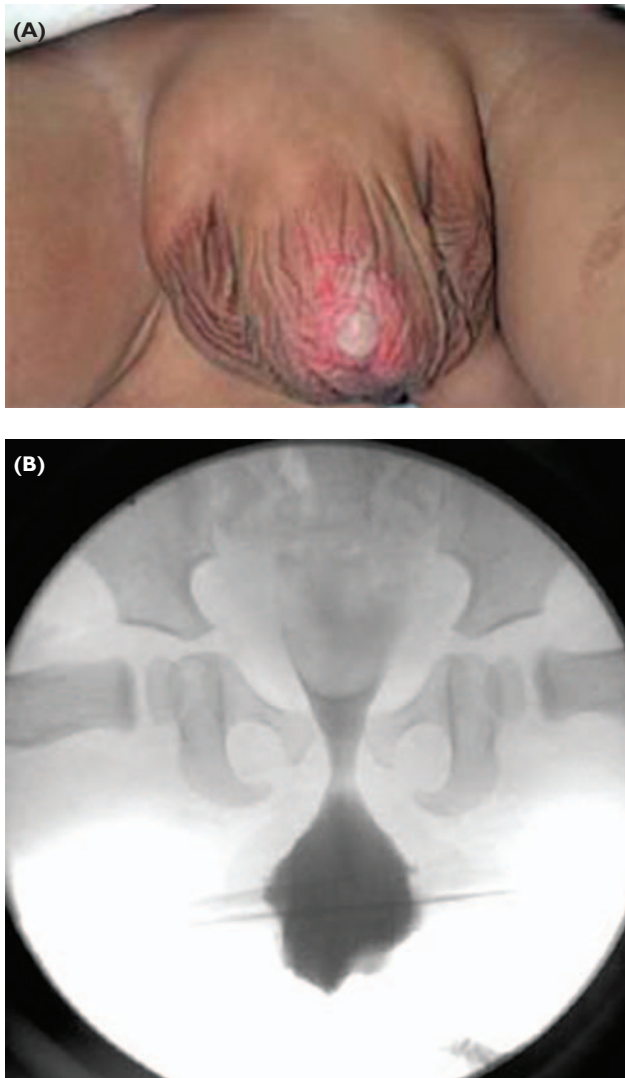


Figure 51.3 Patient with fusiform megalourethra. (A) Gross appearance. (B) Accompanying VCUG study with characteristic radiographic appearance.

delay in canalization of the distal epithelial core, leading to obstruction and proximal dilatation. Others have suggested that embryologic arrest of the mesoderm investing the urethral folds influences the development of erectile tissue and corpora.¹² Finally, a case report noted megalourethra with all corpora intact.¹⁶

Megalourethra is often associated not only with urorectal anomalies such as imperforate anus, prune belly syndrome, and urethral valves, but also with varying degrees of uropathy^{17–19} (Figure 51.3). Diagnosis is made at the time of physical examination, particularly if the child is seen to void. The urethral meatus may be normally placed but patulous. The more rare and severe fusiform type is characterized by a soft, elongated phallus with palpably deficient corpora. Ventral

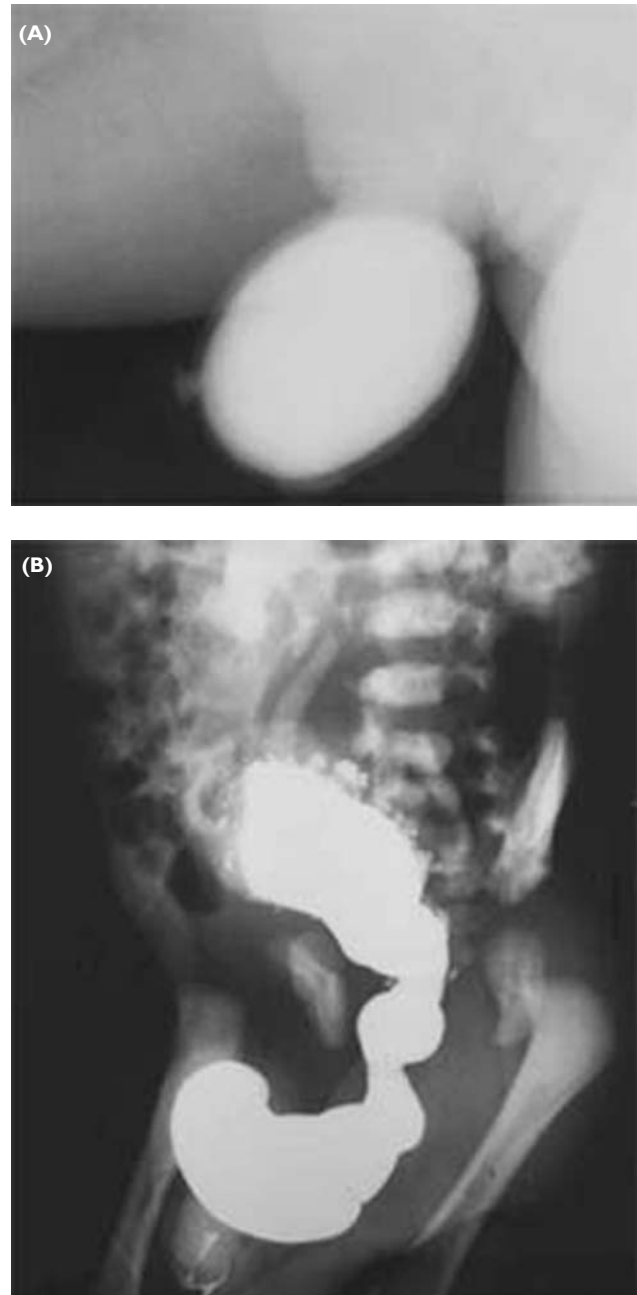


Figure 51.4 VCUG studies depicting (A) fusiform megalourethra and (B) scaphoid megalourethra.

ballooning with voiding is typical of scaphoid megalourethra. Voiding cystourethrography and renal ultrasonography are performed to establish the diagnosis and evaluate the upper tracts (Figure 51.4).

The most favored surgical treatment remains that of Nesbitt,¹² including degloving of the penis, incising the ventral aspect of the urethra, excising the redundant tissue, and fashioning the neourethra over a urethral

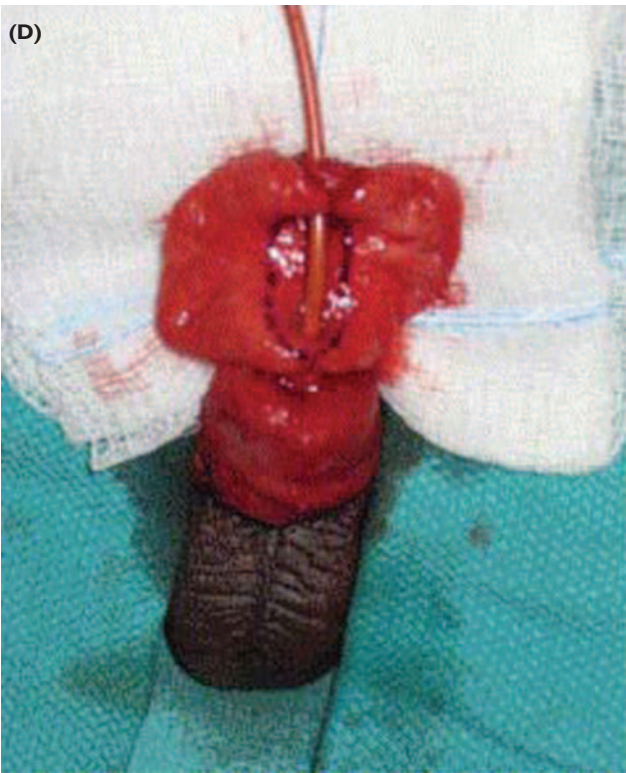
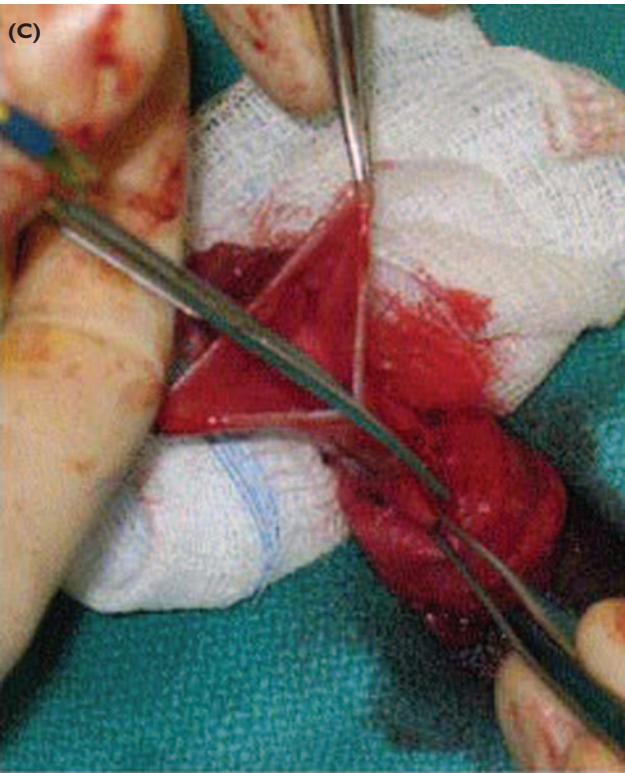
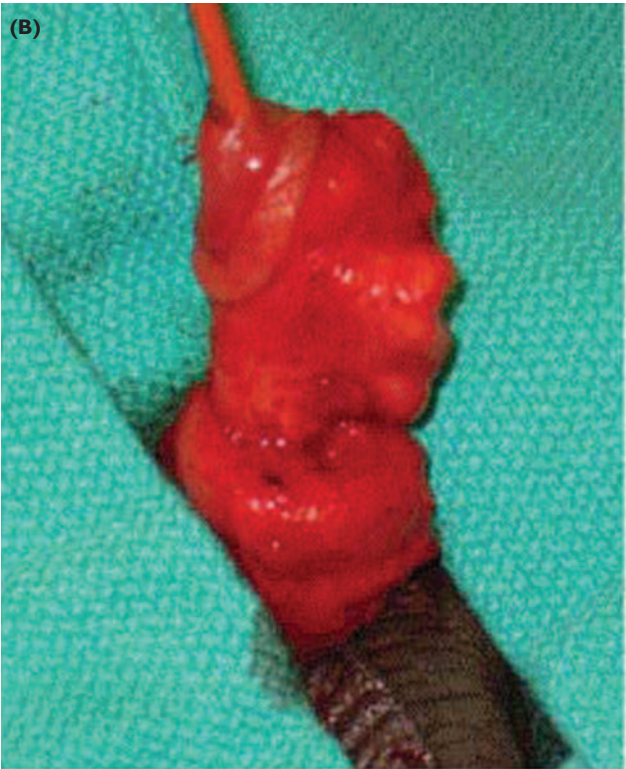


Figure 51.5 (Continued)

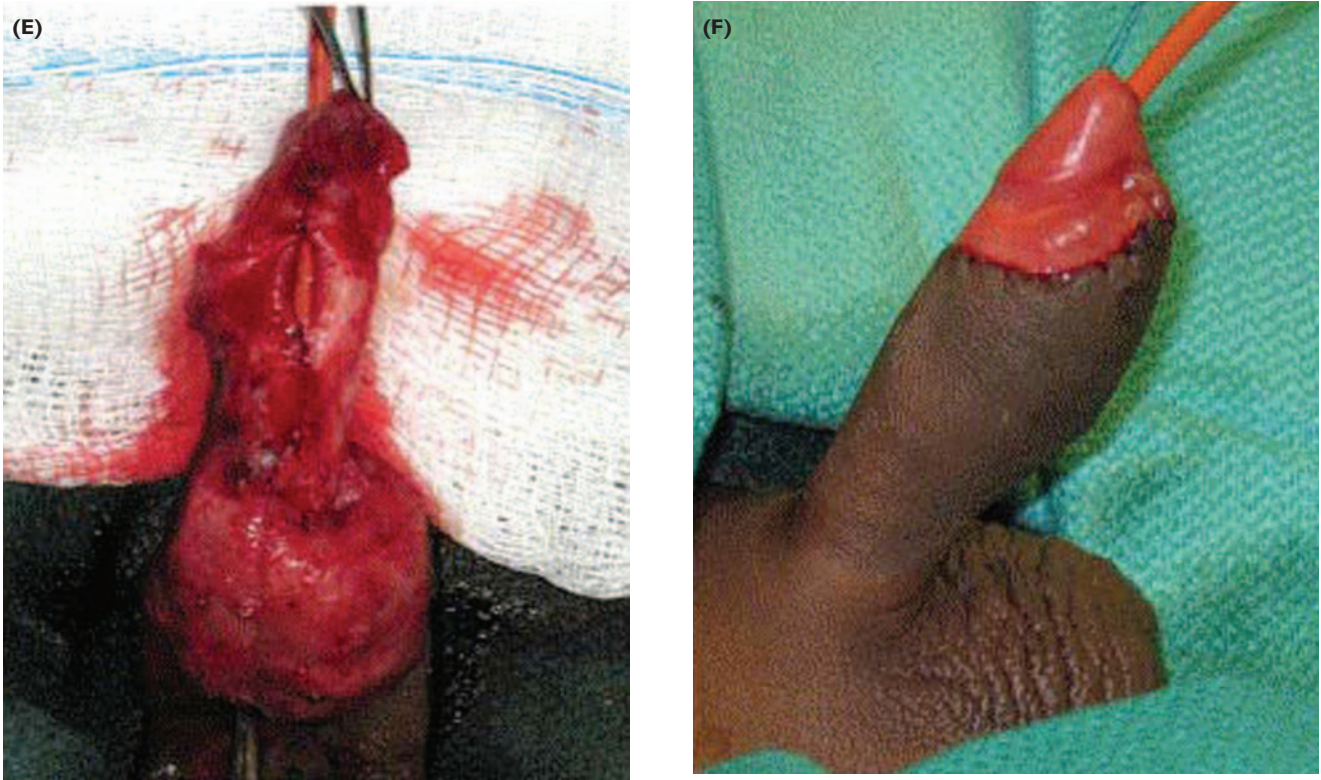


Figure 51.5 Surgical repair of scaphoid megalourethra. (A) Gross appearance, (B) degloved penis with decompressed urethra, (C) ventral incision, (D) demarcation of lines for urethral excision, (E) retubularization, and (F) postoperative appearance after circumcision. From reference 20, with permission.

catheter from the remaining dorsal urethra. The penile skin is then drawn forward and resutured to the corona. A recent case report nicely outlines the surgical repair of scaphoid megalourethra and provides digital video to illustrate the functional anatomy²⁰ (Figure 51.5). The fusiform variety presents a much more difficult surgical challenge, depending upon the amount of corporal tissue present. Some may be impossible to completely repair from a functional standpoint with corporal reconstruction and placement of penile prostheses being necessary as an adult. Ongoing evaluation is critical since uropathy remains a significant problem. Appel et al²¹ noted that 19 of 31 patients with scaphoid megalourethra ultimately developed azotemia or had died from renal failure as did seven of ten with fusiform megalourethra.

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52 Management of acute urethral trauma

Jill C Buckley and Jack W McAninch

Traumatic urethral injuries are uncommon and often require a high index of suspicion particularly in the severely injured patient. Proximal vesicle urinary diversion is often performed in the acutely ill trauma patient to allow for accurate urinary output monitoring and resuscitation. Immediate surgical repair can be technically difficult and should be limited to those patients who sustain penetrating urethral trauma and who are hemodynamically stable. The mechanism and location of injury dictate the acute management. Posterior urethral injuries are often associated with major abdominal and/or pelvic fractures that can be life-threatening and demand immediate attention and resuscitation. Anterior urethral injuries are usually the result of direct trauma to the urethra, with few associated injuries, and are of lower acuity.

MALE URETHRA ANATOMY

The male urethra is anatomically divided into five regions making up the anterior and posterior urethra (Figure 52.1). The posterior urethra is divided into the prostatic urethra, the bladder neck to the apex of the prostate, and the membranous urethra, the tip of the prostate through to the end of the external urinary sphincter. The anterior urethra commences just distal to the membranous urethra consisting of the bulbar urethra, the pendulous urethra, and the fossa navicularis. It is surrounded by the highly vascular corpus spongiosum. The prostate and posterior urethra are located deep within the pelvis and protected anteriorly by the pubic symphysis. The anterior urethra lies outside the bony pelvis thus rendering it more vulnerable to external blunt trauma.

ANTERIOR URETHRAL INJURY

Anterior urethral injuries can present with blood at the meatus, an inability to void, a distended bladder or with extensive penile and/or perineal soft tissue swelling, and ecchymosis. A hematoma that extends down into the perineum or inner thigh or superiorly along the abdominal or chest wall indicates that Buck's fascia surrounding the spongiosum has also been

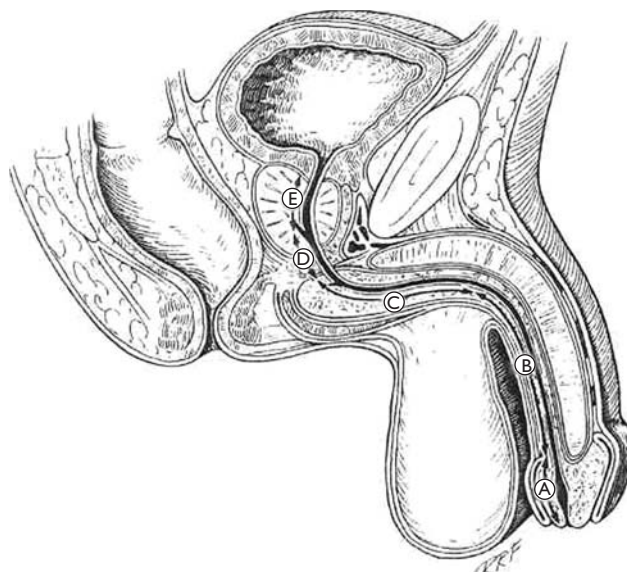


Figure 52.1 Male urethral anatomy. (A) Fossa navicularis. (B) Pendulous urethra. (C) Bulbous urethra. (D) Membranous urethra. (E) Prostatic urethra. From Jordan GH, Schellhammer PF. Urethral surgery and stricture disease. In Droller M. Surgical Management of Urologic Diseases. St Louis, MO. Mosby Yearbook: 1992; p 394. Reference 4a. with permission.

violated (Figure 52.2). Acute urethral injuries occur in 10–20% of penile fractures involving rupture of the corpora cavernosa and should be suspected in any patient unable to void, with hematuria, or blood at the meatus. If a urethral injury is detected with a penile fracture, it should be repaired simultaneously with the corporal cavernosal disruption.¹ Urethrography is the study of choice to diagnose a suspected anterior urethral injury. Alternatively, if urethrography is not available, urethroscopy can be performed by an experienced urologist but is not routinely done as endoscopic visualization is often limited by acute bleeding and edematous tissue with the potential to exacerbate the current injury.

Diagnosis

Retrograde urethrography

In retrograde urethrography (RUG) optimal anterior urethral evaluation is obtained with 45° rotation of the

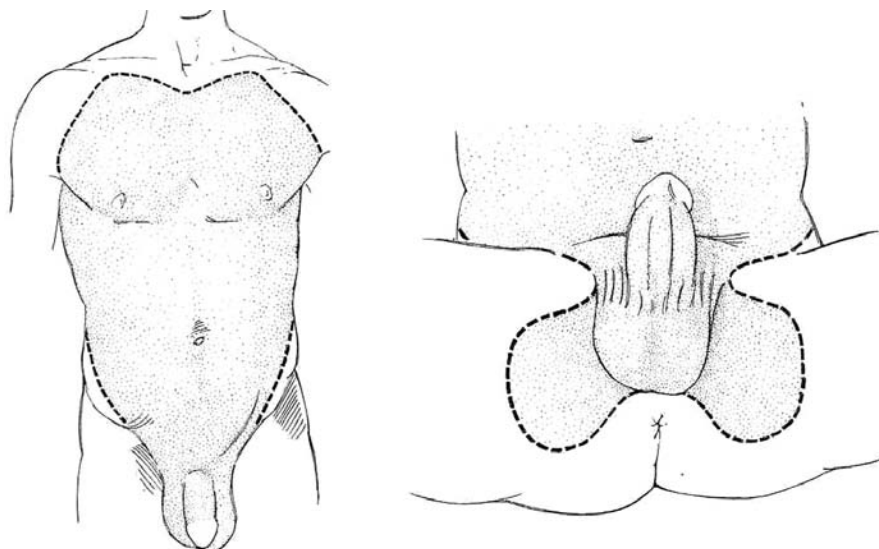


Figure 52.2 Potential extravasation sites with disruption of Buck's fascia. From reference 4b, with permission.

patient's pelvis and bottom leg flexion (Figure 52.3). Proper positioning along with penile stretching allow for an unobstructed lateral view of the urethra. A 12 Fr urethral catheter is inserted just proximal to the fosa navicularis and the balloon is filled with 1.5 ml of fluid. A plain film of the pelvis is obtained. With the penis on stretch, 20 ml of water soluble isotonic contrast is injected into the urethra and a RUG is taken. If no extravasation is seen, the anterior urethra is intact and a urethral catheter can be placed.

Blunt anterior urethral injury

The classic anterior urethral injury is a 'straddle' injury to the bulbar urethra and as the name implies occurs when the perineum sustains a blunt impact force against the pubic bone (Figure 52.4). The bulbar urethra is crushed against the inferior pubic rami resulting in a wide range of urethral injury from contusion to complete disruption. Crush injuries result in extensive soft tissue and spongiosal damage and are not amenable to immediate repair. The extent of injury is difficult to assess which can lead to over aggressive urethral mobilization and suboptimal tissue reconstruction and healing.

If a partial urethral injury is demonstrated on the RUG periurethral extravasation with contrast filling the bladder, a careful single attempt at retrograde urethral stenting can be made. Proper technique and 2% viscous lidocaine lubrication will facilitate successful catheter placement. If successful, the urethral catheter should be left in place for 14 days to facilitate healing and a voiding cystourethrogram (VCUG) or pericatheter urethrogram should be performed at the time of catheter removal. If urinary extravasation is still

present then the catheter should be replaced or remain indwelling for another 7–10 days. Once the catheter is removed indicating complete urethral closure, the patient must be closely monitored for development of a urethral stricture with urinary flow rates and repeat imaging if a slow or difficulty voiding pattern develops. If any difficulty is experienced in placing the urethral catheter no further manipulation of the urethra should be performed and a proximal suprapubic catheter is placed.

Proximal urinary diversion in the form of a suprapubic cystostomy is a safe and reliable way to manage any acute urethral injury and should be used without hesitation. Extensive manipulation in an attempt to place a urethral catheter can result in significant additional trauma and should be avoided.

Penetrating anterior urethral injuries

Isolated stab wounds and low velocity gun shot wounds (GSW) to the anterior urethra should be explored, debrided, and primarily repaired in hemodynamically stable patients.² A retrograde urethrogram can confirm the location of the injury (Figure 52.5). In the pendulous urethra, a circumferential subcoronal incision is made for optimal urethral exposure (Figure 52.6). Penetrating injuries require debridement of non-viable tissue, urethral mobilization, spatulation, and a single layer interrupted anastomosis using fine absorbable suture over a 14–16 Fr silicone catheter. The catheter should be left indwelling for 14 days and a VCUG performed at the time of catheter removal to confirm the integrity of the urethra. If a primary anastomosis is not possible due to a long defect or friable tissue unable to hold suture, marsupialization of the

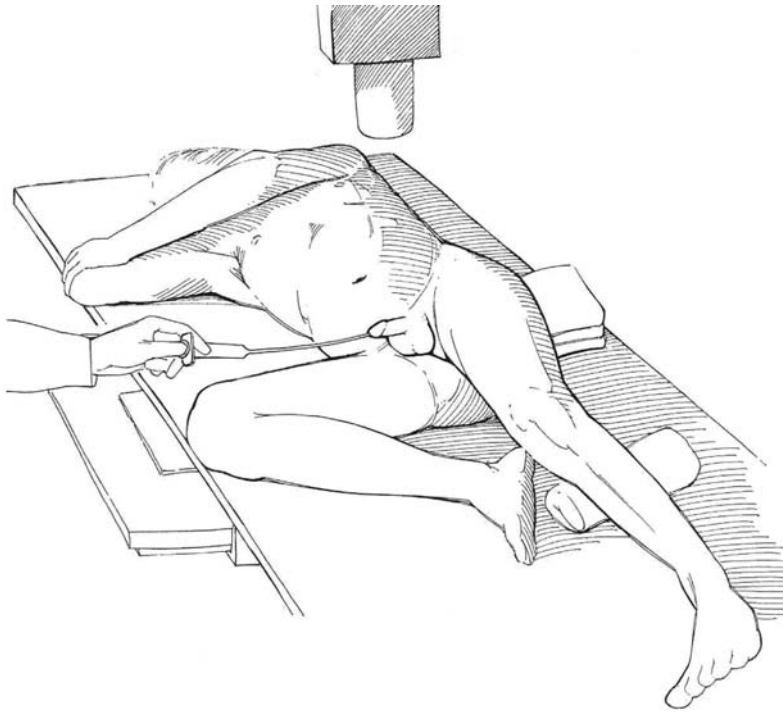


Figure 52.3 Proper positioning and technique for retrograde urethrography. From reference 4c, with permission.

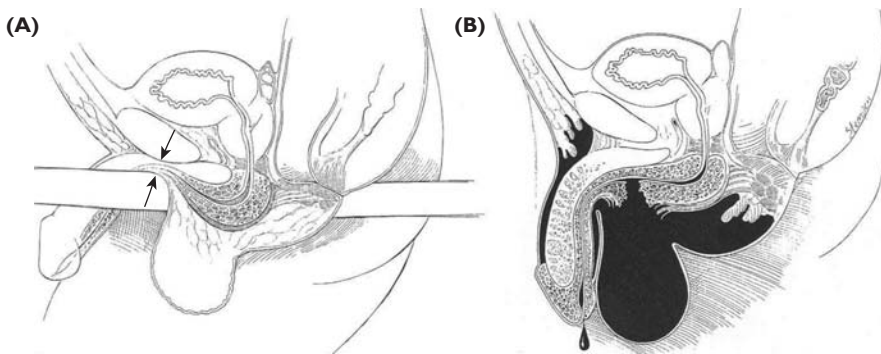


Figure 52.4 Mechanism of blunt anterior urethral trauma. (A) Classic straddle injury crushing the bulbar urethra against the pubic symphysis. (B) Bulbar urethral disruption with associated hemorrhage confined by Colles' fascia. From reference 4d, with permission.

urethra should be performed with proximal urinary diversion.³ A deferred elective staged reconstruction can be undertaken in the following 3–6 months.

An isolated penetrating bulbar urethral injury is an uncommon event due to its protected location below the pubic bone. A low velocity GSW should be explored and repaired via a midline perineal incision as in an elective bulbar urethral stricture repair. Reconstructive principles are applied ensuring wide debridement, urethral spatulation, watertight closure, and stenting. As in all penetrating trauma, debridement of non-viable tissue is important to prevent

infection and abscess formation. A single interrupted layer is performed dorsally compared with a two-layer closure ventrally. In the bulbar urethra, the urethra is eccentrically located dorsally resulting in a thick ventral corpus spongiosum that is best closed in two layers. The inner layer reapproximates the urethral epithelium and the outer layer closes the tunica of the spongiosum to provide hemostasis.⁴ A urethral injury secondary to a shotgun creates a large soft tissue defect not amenable to primary reanastomosis and is managed with proximal suprapubic urinary diversion and delayed reconstruction.



Figure 52.5 Retrograde urethrogram of a gunshot to the anterior urethra with extravasation into the periurethral tissue. Immediate operative exploration and repair was performed. From reference 4e, with permission.

POSTERIOR URETHRAL INJURY

Injuries to the posterior urethra usually occur as the result of severe blunt trauma with major and often life-threatening injuries.⁶ Classically, they are associated

with pelvic fractures and result from a shearing of the membranous urethra displacing the prostate and the prostatic urethra cephalad and posterior with variable degrees of injury to the external striated urinary sphincter (Figure 52.7). Historically, the external sphincter was felt to be severely injured, rendering it non-functional, but recent literature demonstrated both the external rhabdosphincter as well as the smooth muscle sphincter can remain intact.⁵⁻⁷ Recent studies propose the urethral injury associated with pelvic fracture is an avulsion of the membranous urethra from the bulbar urethra rather than a shearing through the membranous urethra. Prostatic disruption, at the time of injury, results in a large pelvic hematoma from injury to the dorsal venous complex and Santorini's venous plexus (Figure 52.8). Life-threatening pelvic hemorrhage occurs as a result of posterior pelvic disruption and bleeding requiring rapid resuscitation and either operative exploration or pelvic angioembolization with more than 30% mortality rate.^{8,9,10}

Pelvic fracture urethral disruptions are the result of a crush injury that tears the distal portion of the membranous urethra anchored by the pubic symphysis anteriorly, from the proximal bulbar urethra fixed by the perineal membrane. Classic findings are 1.) pelvic fracture, 2.) blood at the meatus, 3.) high riding prostate on

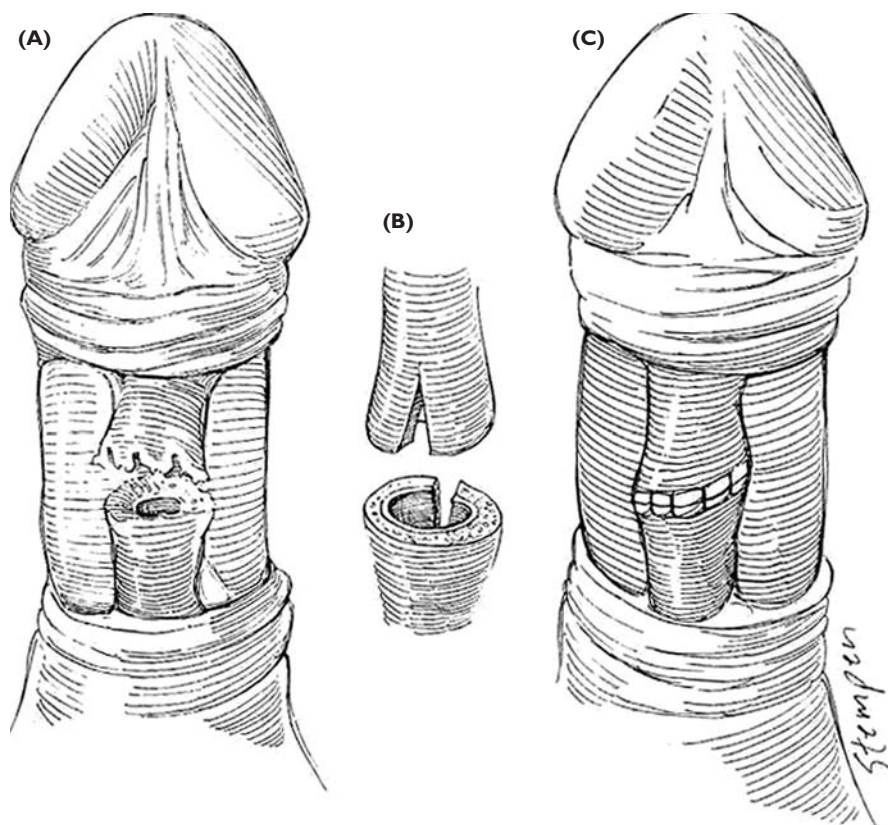


Figure 52.6 Primary repair of a penetrating anterior urethral injury. (A) Exposure and assessment of injury. (B) Debridement of non-viable tissue and urethral spatulation. (C) Interrupted end-to-end anastomosis. From reference 4f, with permission.

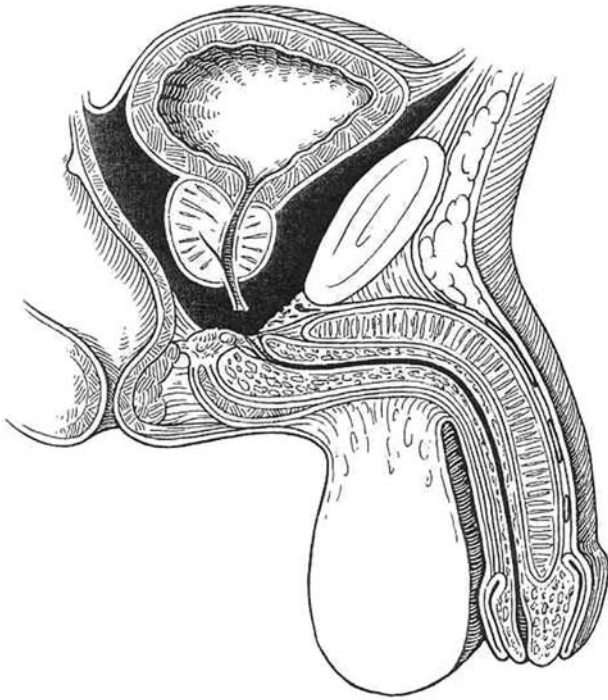


Figure 52.7 Pelvic fracture distraction injury. From reference 5a, with permission.

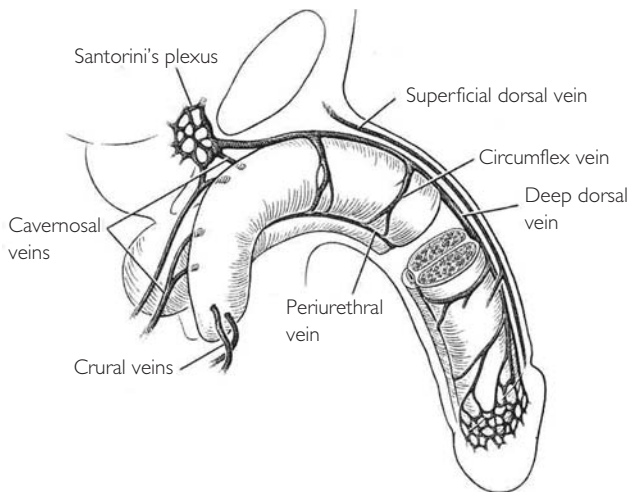


Figure 52.8 Venous drainage of the penis and urethra. From reference 5c, with permission.

digital rectal examination (DRE), 4.) an inability to void, and/or 5.) a palpable bladder. The prostate can be difficult to palpate secondary to hematoma or edematous tissue. The DRE is important to perform, however



Figure 52.9 Complete posterior urethral distraction injury.

to assess rectal tone and can identify a rectal injury which is often intimately related with a lower urinary tract injury. Any of the above clinical findings could be present or absent thus prompt diagnosis depends on a high level of suspicion in a critically ill trauma patient. The immediate goal is to stabilize the patient from life-threatening injuries and provide immediate urinary drainage through suprapubic cystostomy.

Diagnosis

A retrograde urethrogram is the diagnostic study of choice. Unlike as described above for evaluation of the anterior urethra, rotation of the pelvis may not be feasible due to an unstable pelvic fracture. The immediate goal is to evaluate the continuity of the urethra which can be achieved despite suboptimal pelvic positioning. A plain film is taken to assess the bony anatomy followed by placement of a 12 Fr urethral catheter in the distal urethra with 1.5 ml injected into the balloon. A single shot urethrogram with 20 ml of water soluble contrast is taken. A partial urethral tear is identified by extravasation with contrast passing proximally into the bladder. A complete urethral disruption demonstrates contrast extravasation into the surrounding perivesicle tissue without filling the bladder (Figure 52.9). If no extravasation is identified, the urethra is intact and a urethral catheter can be placed using sterile technique.¹¹ A cystogram and/or upper tract evaluation is performed as indicated.

In the event that a urethral catheter was placed prior to proper evaluation in a patient with a suspicion

of a lower urinary tract injury, a periurethrogram can be performed. A 14-gauge angiocatheter is placed into the urethra next to the urethral catheter and water soluble contrast is injected. This allows evaluation of the urethra and confirms proper catheter placement in the bladder. If a urethral injury is detected, the urethral catheter should remain in place for 4–6 weeks to allow healing. The patient should be placed on antibiotics and a voiding cystourethrogram is performed at the time of catheter removal to confirm complete urethral continuity. An incorrectly positioned catheter outside the urethra should be removed and a suprapubic catheter placed.

Initial posterior urethral distraction management

The initial focus should be on complete evaluation, resuscitation, and stabilization of the patient by the trauma surgeons. If the patient is acutely unstable, then immediate cystostomy catheter urinary diversion should be performed. If an abdominal exploration is being performed, an open cystostomy catheter can be placed transperitoneal at the completion of the exploration with minimal additional operative time required. This approach avoids entering the pelvic hematoma preventing additional blood loss, tissue manipulation, and introduction of infection. If an abdominal exploration is not going to be performed, a percutaneous suprapubic catheter is placed. If gross hematuria is noted on catheter placement, the bladder should be formally explored for a concurrent bladder injury.¹²

Acute surgical management

In a patient, who has sustained a concomitant rectal injury, bladder neck injury, or severely distracted ‘pie in the sky’ bladder, immediate surgical management is warranted.^{11,13} Fecal contamination of the pelvic hematoma can lead to pelvic abscesses, rectourethra fistula formation, and dense fibrosis with immediate and long-term morbidity and mortality. A diverting colostomy should be performed and an attempt at primary realignment can be made in a hemodynamically stable patient. If alignment cannot easily be achieved with endoscopic visualization, an open suprapubic catheter should be placed and brought out directly through the midline for anticipated delayed reconstruction. Excessive manipulation risks worsening the acute injuries, creating additional scarring of the urethra, bladder, or

pelvis making the delayed repair significantly more complex.¹⁴

Bladder neck injuries, although uncommon, can occur simultaneously with pelvic fracture urethral disruptions and should be reconstructed at the earliest postinjury opportunity.¹³ The initial pelvic fracture combined with the delayed posterior urethral repair invariably will leave the distal external sphincter poorly functioning with continence dependent on the bladder neck sphincter. A midline vertical cystotomy is made and the bladder neck is reapproximated with absorbable sutures. Realignment of the posterior urethral distraction can be cautiously attempted by an experienced surgeon who is intimate with pelvic and urethral anatomy as stenting the bladder neck repair is preferred.

Early surgical intervention is also warranted when a wide separation of the urethral ends is discovered secondary to a large pelvic hematoma. A complex long urethral defect will make the delayed repair difficult, diminishing the chance of a successful one-stage reconstruction. A vertical low abdominal incision is made entering the dome of the bladder through the peritoneum. This avoids entering the pelvic hematoma. A cystotomy is made followed by an endoscopically assisted urethral realignment using a Seldinger technique. Unstable patients should be managed according to resuscitation guidelines with placement of a suprapubic catheter. A delayed realignment procedure may be considered after resolution of the patient’s life threatening injuries.^{11,13,15}

Initial management in non-life-threatening injuries

Two schools of thought exist as to the optimal management of acute posterior urethral injuries in a non-critically ill patient: early realignment of the urethra or initial suprapubic drainage and delayed repair. The literature is limited by small series, limited follow-up, various realignment techniques, and vague definitions of success. No randomized prospective study has been performed to address this issue directly, thus it is the decision of the treating physician as to which treatment option will best serve the patient. Either approach can be successful when performed by an experienced urologist with comparable risks of impotence and incontinence, and the management will largely be determined on a case by case basis.¹⁶ For physicians who are not familiar or comfortable with pelvic and urethral trauma, the safest management option is to place a suprapubic catheter and refer the

patient for delayed repair at a tertiary referral center with expertise in urethral reconstruction.

Early primary repair

Early primary repair is not recommended as this requires releasing the pelvic hematoma leading to significant bleeding and poor visualization. Tissue dissection is difficult and can unnecessarily damage the neurovascular bundle and/or external sphincter as debridement and urethral mobilization are required. Unacceptably high incontinence (20%), impotence (44%), and stricture (69%) rates resulted in the abandonment of this approach.^{10,14,17}

Suprapubic urinary diversion

In the 1970s a shift occurred towards suprapubic drainage and delayed repair based on the long-term morbidity of primary posterior urethral repair as stated above. The exchange for decreased impotence (11%–19%) and incontinence (2%–4%) rates by suprapubic urinary diversion only, was acceptance of a posterior urethral defect/stricture 97–100%.^{18,19}

Many expert reconstructive urologists prefer minimal intervention at the acute injury and place a suprapubic catheter with acceptance of delayed repair. The vast majority will have an obliterative defect that will require a complex posterior urethral reconstruction. In experienced reconstructive urologist hands, a one-stage repair has a more than 90% success rate (defined as no additional procedures) and provides a definitive solution for the patient.^{5,20} Purposed benefits to this approach are easy and rapid performance in an acute trauma situation, prevention of blood loss and additional tissue injury by avoiding pelvic dissection and decrease risk of pelvic abscess formation. Posterior urethral distraction defects are complex urethral injuries that require the expertise of an experienced urethral reconstructive surgeon to achieve successful repair.

Primary realignment

Improved endoscopic equipment, techniques, and familiarity led to a renewed interest in primary realignment with current literature showing comparable impotence and incontinence rates with an approximately 50% decrease in urethral stricture rates.^{16,19,21,22} Proposed benefits are a shorter, more anatomically aligned stricture that may be amenable to internal

urethrotomy or dilatation, a technically easier delayed posterior urethral reconstruction or complete avoidance of additional procedures in a select number of patients. Disadvantages include additional operative time and/or a second operative procedure and anesthetic, potential exacerbation of the existing injury creating a more complex repair and increased risk of infection. To optimize success, some authors advocate initial suprapubic drainage followed by delayed realignment once the patient has been appropriately resuscitated and stabilized. This avoids lengthy procedures in critically ill patients and allows for stabilization of the pelvic hematoma.^{10,13,15}

Primary urethral realignment techniques

Many techniques have been described to bridge the urethral defect created by a pelvic crush injury with varying success. These include simple urethral catheter placement across the defect, catheter to finger, sound to finger, and sound to sound techniques (Davis interlocking sounds); endoscopically assisted catheter realignment; magnetic tipped catheters, and pelvic hematoma evacuation and primary repair. Contemporary management utilizes direct endoscopic visualization with flexible cystoscopy and/or fluoroscopy from either or both a retrograde and antegrade direction (Figure 52.10). Transvesically, a flexible cystoscope can be passed through the bladder neck towards the distraction. If the distal urethral end can be identified a wire is advanced and a catheter placed in the standard Seldinger technique. If this is unsuccessful, a second flexible cystoscope is placed through the pendulous urethra and advanced towards the light of the antegrade cystoscope. A wire is placed followed by a Council catheter which should remain indwelling for 4–6 weeks. Blind instrument passage is not recommended at the risk of converting a partial urethral tear to a complete avulsion or dramatically lengthening the distraction distance. Extreme caution is necessary in performing urethral realignment and it should be limited to individuals experienced in urethral and pelvic surgery. Suprapubic urinary diversion is always an acceptable management option.

Penetrating posterior urethral injuries

Penetrating injuries to the posterior urethra should be explored and primarily repaired. Although these are uncommon events, they are associated with high



Figure 52.10 Antegrade flexible cystoscopy through the bladder neck to visualize the site and extent of urethral injury. If the distal aspect of the urethra can be identified a wire is passed under direct vision and a Council tipped catheter placed. From reference 4g, with permission.

morbidity and mortality especially in the setting of a concurrent rectal injury.⁶ Low velocity GSW injuries require local debridement and primary tissue reapproximation over a urethral catheter with absorbable suture. The bladder should be explored for any additional injuries and repaired from the inside with absorbable suture. Entering the lateral pelvic hematoma should be avoided if possible and is best accomplished by making a midline vertical skin and bladder incision. If significant hematuria is present a cystostomy catheter can be placed to assist in drainage. If a rectal injury is present, a diverting colostomy is performed by the trauma surgeon.

Pediatric trauma

Pediatric urethral injuries are generally treated as in the adult. Some speculate a higher incidence of bladder and urethral trauma due to the prepubertal prostate and relatively more intra-abdominal location of the bladder.²³ Mechanism of injury, presentation and physical examination direct the initial evaluation as in the adult patient, to allow a prompt diagnosis of

a urethral injury. Contrast evaluation of the urethra and the bladder with a RUG and cystogram, respectively, should be carried out to guide initial management as outlined above. In children we do not recommend any urethral manipulation and place a cystostomy tube with anticipated delayed repair assuming a concurrent bladder neck injury or rectal injury is not present.

Female urethral injuries

Unlike the male urethra, the female urethra is short and mobile without bony fixation making a urethral injury a rare event. The diagnosis is difficult to make and often delayed. Female urethral injuries do not occur as an isolated event and should be suspected in a patient with a pelvic fracture and/or vaginal laceration. Blood located at the vaginal introitus demands careful vaginal examination and radiographic evaluation initially, as well as in the acute peritraumatic injury period in a female with voiding difficulties.²⁴ Injury to the bladder neck can occur simultaneously as the most common injury is a partial longitudinal tear which should be reconstructed at the time of exploration and primary urethral repair with absorbable suture.²⁴ Voiding difficulties in the acute peri-traumatic injury period can indicate a missed lower urinary tract injury and should be evaluated as outlined above.

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53 Posterior urethral reconstruction

Neil H Grafstein and George D Webster

Posterior urethral distraction injuries most commonly result from high impact trauma to the pelvis and perineum. While penetrating injuries to the posterior urethra do occur, at least 90% are caused by blunt trauma from motor vehicle accidents, falls from heights, or occupational injuries that are of sufficient severity to cause pelvic fractures.¹ Urethral injury is rare in the absence of a pelvic fracture but, conversely, urethral injuries are seen in only 3–25% of pelvic fracture cases.² It is perhaps due to its rarity that the optimal management of posterior urethral injuries has in the past been controversial and in the present continues to evolve.

This chapter focuses on the management of traumatic posterior urethral injuries typically sustained in association with pelvic fracture. The iatrogenic posterior urethral stricture that is a consequence of transurethral resection of the prostate or radical prostatectomy is a distinct and unrelated entity discussed in Chapter 67.

ANATOMY OF THE POSTERIOR URETHRAL DISTRACTION DEFECT

The male posterior urethra comprises the membranous urethra, the prostatic urethra, and the bladder neck. Compared with the anterior urethra, which includes the fossa navicularis, bulbar, and pendulous urethra, the posterior urethra is relatively immobile due to its muscular and ligamentous attachments to the pelvic bone: the prostatic urethra to the pubic symphysis by the puboprostatic ligaments and the membranous urethra to the ischiopubic rami via the urogenital diaphragm. Additionally, the muscle fibers of the distal sphincteric mechanism that comprise the thickness of the membranous urethra terminate at the perineal membrane which marks the junction of the membranous and bulbar urethra. These two factors, the relative immobility and the abrupt termination of the sphincteric fibers, render the bulbar-membranous transition point an anatomically weak location that is vulnerable to injury. When pelvic trauma is sustained, the bladder neck, prostate, and membranous urethra ascend together in a cephalad and posterior direction which will distract the posterior urethra away from the anterior urethra. The

spectrum of urethral injury can range from an elongation or stretching of the membranous urethra to a complete disruption of the bulbomembranous urethra. At the mild end of the spectrum, traumatic detachment of the vesicoprostatic attachments to the pelvic floor leads to pelvic hematoma formation. The bladder and posterior urethra are lifted away from the anterior urethra on the enlarging hematoma thereby elongating the membranous urethra. This stretching injury will generally not lead to urethral stricture formation but can lead to fibrosis of the distal sphincteric muscle fibers which may functionally compromise this continence mechanism. When the magnitude of the trauma is more severe a tear results at the membranous-bulbar urethral junction. In 65% of cases this tear is complete.³ With partial tears some urethral continuity remains intact and may heal with a non-obliterative or short stricture. However, with a complete transection, the urethral ends are separated and urethral continuity is lost. The distance between the transected urethral ends will be determined by the size of the hematoma and the degree to which the prostate and membranous urethra were detached from the pubic bone and pelvic floor. After the acute inflammatory cascade, this distance will be bridged by a fibrotic process that is most accurately termed a ‘pelvic fracture urethral distraction defect’ (PFUDD) rather than a urethral stricture, which erroneously connotes narrowing of an intact lumen with epithelial continuity. Over time, the hematoma liquefies, organizes, and shrinks, and the vesico-prostatic complex descends, leaving the ultimate length of the PFUDD somewhat shorter than the length of the acute defect, even without surgical intervention.

SEQUELAE OF THE PELVIC FRACTURE URETHRAL DISTRACTION DEFECT

The two most common long-term consequences of a PFUDD, apart from the urethral discontinuity, are urinary incontinence and erectile dysfunction (ED). These complications have an anatomic basis and are most often the direct result of the initial traumatic injury. Nevertheless, ED and incontinence can potentially be exacerbated by surgical attempts to repair the PFUDD.

Table 53.1 Classification of posterior urethral injuries based on retrograde urethrogram

Type I	Membranous urethra stretched but intact; no extravasation
Type II	Partial/complete rupture of membranous urethra above urogenital diaphragm; extravasation into pelvis
Type III	Partial/complete rupture of membranous urethra extending into proximal bulbar urethra; extravasation into perineum
Type IV	Concomitant injury to bladder neck

From reference 9, with permission.

Under normal circumstances, urinary continence is ensured by a dual intrinsic sphincteric mechanism that is intimately associated with the posterior urethra. Continence will be preserved if the integrity of at least one of these intrinsic components, either the proximal or distal sphincter, is preserved. The proximal sphincter is found at the bladder neck while the distal sphincter comprises the wall of the posterior urethra from the verumontanum to the distal most portion of the membranous urethra. These intrinsic sphincters are composed of slow-twitch muscle fibers capable of maintaining tonic control against urinary loss. Additionally, an extrinsic sphincter that can be voluntarily contracted to interrupt the urinary stream surrounds the membranous urethra but this external rhabdosphincter, or 'voluntary sphincter', does not contribute to static continence. As a result of the pelvic trauma, and likely compounded by surgical intervention, the intrinsic distal sphincteric mechanism is compromised. Therefore, continence, after treatment of a PFUDD, relies solely on the proximal sphincter mechanism at the bladder neck. Those patients with concomitant bladder neck injury or any prior bladder neck procedure (e.g. transurethral resection of the prostate, prostatectomy) are at high-risk for incontinence after a PFUDD.

ED is a common consequence of posterior urethral distraction injuries seen in 24–82% of patients, depending on the criteria used to define its presence.^{4–6} Pelvic fractures alone can lead to ED but when fractures are associated with urethral injury the incidence increases eight-fold.⁷ In a previously reported series from our institution, 62% of PFUDD patients had ED prior to perineal urethrostomy and no patients had de novo ED postoperatively, consistent with the notion that ED is a consequence of the initial trauma, rather than the repair. The majority of ED cases are of neurogenic origin secondary to traumatic disruption of the cavernous nerves which course posterolateral to the prostate and then laterally on the membranous urethra. In one study of 25 consecutive posterior urethral injuries, vascular compromise was identified in only 28% of patients with ED, while arterial inflow, as seen on duplex ultrasound, was spared in the remainder.⁵ Mark et al had an

89% success rate when treating PFUDD patients with intracavernous vasoactive agents, further suggesting a neurogenic etiology.⁸

DIAGNOSIS

Posterior urethral injury should be suspected in a pelvic trauma patient who presents with blood at the meatus, a perineal hematoma, or is unable to void. A rectal examination performed at the time of the trauma survey may reveal a high-riding prostate secondary to cephalad displacement by the pelvic hematoma, but this examination is notoriously inaccurate as the pelvic hematoma precludes identification of landmarks. Nevertheless, the rectal examination is important as it will identify an associated rectal injury. When these signs and symptoms are present or if a urethral catheter could not successfully be passed during resuscitation in the trauma unit, a retrograde urethrogram (RUG) must be obtained. Technical considerations in performing the RUG vary between institutions. Our preference is to place a small Foley catheter into the fossa navicularis and inflate the Foley balloon with 1–2 ml of sterile water. With the patient in an oblique position, radiographs are taken during the injection of approximately 25 ml of contrast. Urethral injury is confirmed when extravasation of contrast is seen. If a RUG must be deferred either due to lack of availability or because the patient is unstable, a percutaneous cystostomy tube can be placed to emergently drain a distended bladder. The urethra should be evaluated with a RUG once the patient is more completely resuscitated.

A commonly used classification scheme based on the RUG findings, as proposed by Colapinto and McCallum and later amended by Goldman et al, is presented in Table 53.1. This classification of 'posterior urethral injuries' according to the anatomic site of urethral disruption highlights the point that urethral injuries associated with pelvic fracture are not necessarily limited to the posterior urethra. In fact, the most common type of urethral injury (type III) involves the proximal bulbar urethra.⁹

MANAGEMENT OF THE PELVIC FRACTURE URETHRAL DISTRACTION DEFECT

The initial management of a posterior urethral injury is the subject of much debate in the literature. However, there are two generally agreed upon 'truths' in the immediate management of posterior urethral disruption injuries. First, emergency primary suture repair of the urethra, with the hematoma evacuation and urethral debridement that is usually required, should be avoided except in rare circumstances (discussed below). Such primary surgical anastomotic repair and even primary open realignment (discussed below) is associated with an unacceptably high morbidity rate including incontinence and ED rates of 20% and 40%, respectively. Additionally, re-stricture formation is seen in up to 69% of patients.³

A second dogma of acute management is that suprapubic cystostomy, followed by delayed management of the stricture that almost inevitably results, is always an acceptable strategy. With incontinence rates of less than 5% and ED in less than 20% of cases,^{3,10} initial suprapubic tube placement without realignment of the urethra is considered the gold standard of acute management. Although urethral healing with total patency may result after partial urethral injury,¹¹ urethral discontinuity and a scarred PFUDD are the expected consequences of suprapubic tube management in 83–100% of patients.¹² Although 'stricture' formation is the rule, delayed surgical repair will successfully restore urethral continuity in more than 95% of cases^{4,13–15} and can be reliably accomplished via a perineal approach. After the initial suprapubic tube placement, surgical repair is generally deferred for 3–6 months during which time the pelvic hematoma will be maximally organized and the distracted bladder-posterior urethral complex will descend. This convalescence period allows the PFUDD to contract to its mature length which in the majority of cases will be less than 2 cm¹ and amenable to a one-stage perineal urethroplasty.

Suprapubic tube placement is a basic procedure that is readily offered in the emergency setting even by urologists inexperienced in urethral distraction injuries. This widespread availability combined with the low morbidity and high ultimate success rates render initial urinary diversion with delayed urethroplasty the preferred strategy in many medical centers. A perceived disadvantage is that patients are committed to a complex reconstructive procedure that, although successful, is all but exclusively performed at select referral centers by experienced surgeons with significant expertise in perineal reconstructive surgery.

Also, a significant number of patients will be undergoing orthopedic procedures to reduce pelvic fractures. Theoretically, an indwelling suprapubic tube may compromise surgical access to the pelvis or may serve as a long-term nidus to infection that may jeopardize the hardware used in internal fixation. Although these authors have not found this to be a limiting factor, some insist on open suprapubic tube placement rather than percutaneous placement in order to strategically place the tube at the most cephalad location within the dome of the bladder.

Delayed primary realignment

The term 'delayed primary realignment' is used in contradistinction to primary repair or primary anastomosis which as discussed above is fraught with unacceptable morbidity. The goal of delayed primary realignment is to bridge the defect between the severed urethral ends with a catheter but at the same time avoid the extensive pelvic dissection necessary for primary suture repair. Pelvic hematoma disruption, which may lead to hemorrhage that is surgically difficult to control, and debridement of traumatized tissue, are two steps necessary for a viable sutured anastomosis. However, they are also the purported culprits of the morbidity historically associated with primary repair. In delayed primary realignment, these maneuvers are omitted and intervention is initiated after the hematoma has stabilized thereby potentially reducing the risk of bleeding, erectile dysfunction, and urinary incontinence. The timing of delayed primary realignment, whether hours or days after presentation to the trauma unit, should be made on an individual basis taking into consideration the magnitude of patient injury and overall stability.

The original descriptions of primary realignment called for an open approach with suprapubic and cystotomy incisions. Once intravesical access to the bladder neck was achieved, a catheter was manipulated across the urethral disruption into the bladder. Various techniques ranging from the retrograde passage of a urethral catheter that was manually guided into the bladder to the more elaborate use of Davis interlocking sounds are well described. Despite the antegrade and retrograde access, passing urethral sounds or catheters even with digital manipulation is essentially a blind procedure and risks disruption of the pelvic hematoma with potential for further bleeding and further injury to erectile neurovascular structures and to the sphincter mechanism.

Recent novel endoscopic approaches which allow for direct vision and minimal manipulation have brought

primary realignment back into the realm of possible acute management options. Simple retrograde passage of a flexible cystoscope may enable passage of a guidewire across the injured posterior urethra into the bladder, over which a Council tip urethral catheter can be placed. This basic endoscopic strategy avoids the need for suprapubic access and can be done at the bedside or in the trauma unit but its success is likely limited to cases of partial urethral tears. When retrograde access alone does not allow for placement of a catheter, a suprapubic cystostomy is performed. If the patient is unstable at initial presentation or if concomitant injuries preclude operative intervention, a suprapubic tube can be placed and definitive management either deferred for an extended period of time (as discussed above) or delayed for a few days to weeks when a further minimally invasive attempt at realignment can be made. Once the patient is a candidate for general anesthesia the suprapubic tube tract is dilated to accommodate a flexible cystoscope that is then advanced in an antegrade fashion into the posterior urethra. In order to identify the distal end of the severed urethra, a second flexible cystoscope,¹² or a white urethral catheter (Figure 53.1) is passed via the urethral meatus toward the defect. The suprapubic endoscope then follows the light of the second cystoscope, or the white urethral catheter, through the hematoma into the distal urethra and out through the urethral meatus while simultaneously withdrawing the second cystoscope. A guidewire is inserted through the suprapubic cystoscope and the cystoscope is withdrawn. A Council tip catheter is threaded over the wire into the bladder thereby realigning the urethra. Using a second flexible cystoscope through the penis, rather than a catheter, may be advantageous when visualization of the catheter or cystoscope through the hematoma is poor. A wire can be advanced into the hematoma via the suprapubic cystoscope and a grasper inserted through the retrograde cystoscope can be used to pull the wire into the anterior urethra. The wire can be grasped either under direct endoscopic vision or via fluoroscopic guidance and brought out through the external urethral meatus.¹⁷ Although techniques utilizing rigid instruments are well described and may provide better visibility, flexible endoscopy can be performed in the supine position and is preferable for pelvic fracture patients in whom the lithotomy position may be contraindicated.

Once the urethra has been stented, the catheter is left indwelling for 4–6 weeks. A peri-catheter retrograde urethrogram is then obtained and if contrast extravasation is absent, the urethral catheter is removed and a voiding trial conducted.

Although smaller series using this approach have reported up to a 94% stricture rate,¹⁸ larger series^{19,20}

and pooled data suggest that endoscopic realignment may promote urethral healing without urethral stricture in approximately 50% of cases.¹² Reported ED and urinary incontinence rates in larger series range from 14 to 34% and 0 to 18%, respectively, and are likely consequences of the initial pelvic injury.¹² This seems to confer a significant advantage over suprapubic tube management where stricture rates approach 100%. However, these results must be understood within the limitations of retrospective studies and a lack of randomized prospective trials. A selection bias is likely present in reports comparing delayed primary realignment with initial suprapubic tube diversion alone and later/secondary repair of the defect; patients with the most severe of urethral injuries and those patients with multiple concomitant injuries are more likely to have been managed with suprapubic tube. Thus critics argue that the lower stricture rates reported with endoscopic realignment may be more a reflection of the favorable characteristics of the initial urethral injury than of a treatment benefit. However, since ED and incontinence rates are not adversely impacted and since stricture can be avoided in at least a subset of patients, delayed primary endoscopic realignment must be considered a viable treatment option. Furthermore, even when strictures do form after endoscopic realignment they are invariably amenable to a perineal anastomotic urethroplasty. In fact, early realignment often simplifies subsequent urethroplasty by decreasing the length of the urethral defect and minimizing the surgical steps needed to achieve a tension-free anastomosis.¹⁵

Indications for acute surgical intervention

When posterior urethral injury is associated with rectal injury, urgent intervention is indicated in order to avoid infection of the pelvic hematoma. In addition to urethral re-alignment, the pelvic hematoma should be evacuated and the fecal stream diverted via a sigmoid colostomy.

Because future continence after posterior urethral disruption relies on a functional bladder neck, bladder neck lacerations should be repaired as soon as the patient is hemodynamically stable. Devitalized tissue should be debrided and the bladder neck reconstructed over a stenting catheter.

Delayed repair

At the time of urethral injury, a suprapubic tube is placed for urinary drainage. Repair of the urethral defect is then deferred for a period of 3–6 months to

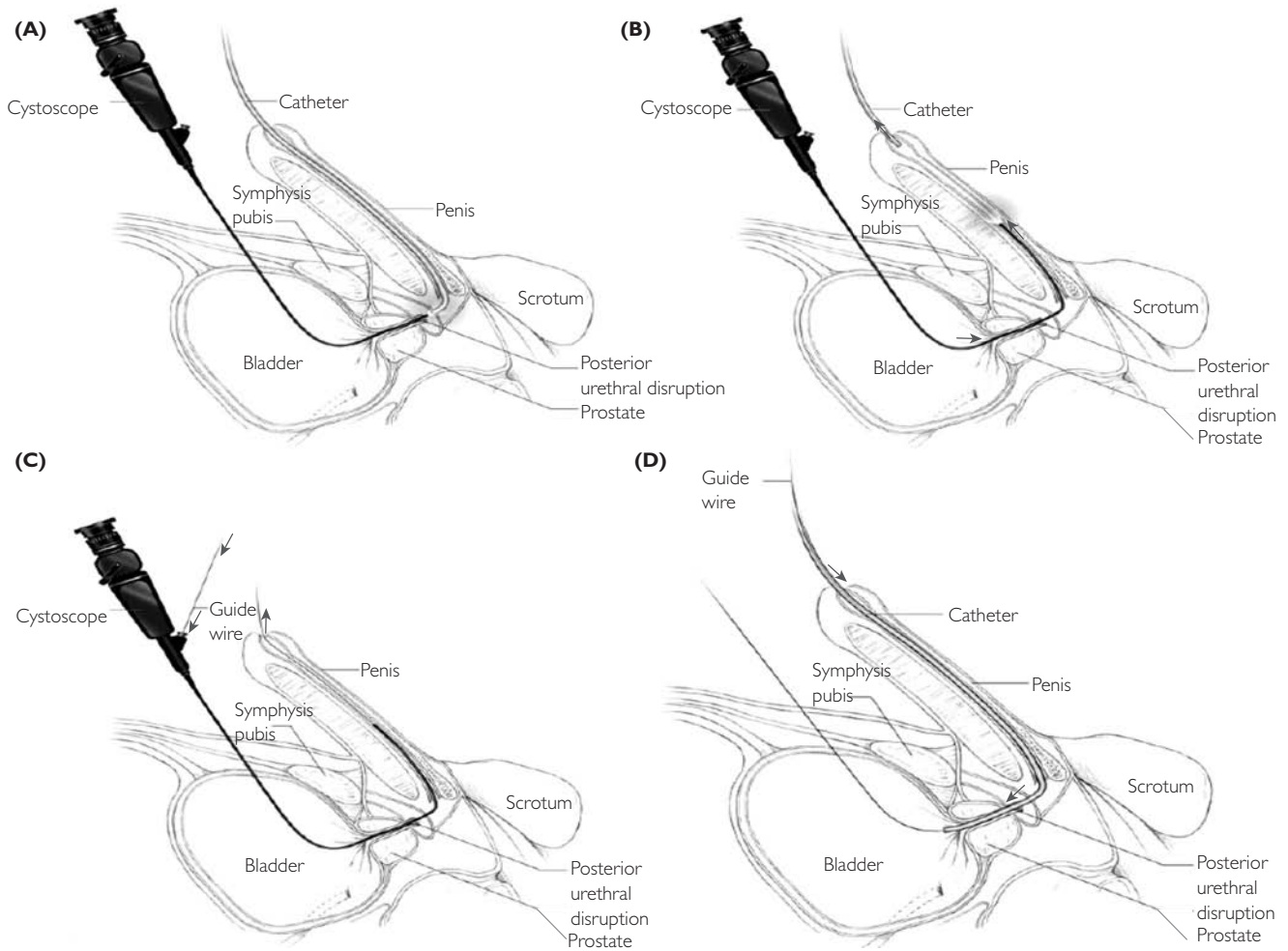


Figure 53.1 (A) Urethral catheter placement aided by antegrade cystoscopy through a small cystotomy incision. (B) Catheter is withdrawn as the cystoscope follows to urethral meatus. (C) Guidewire is advanced through cystoscope and the scope is withdrawn. (D) Foley catheter is placed over wire per urethra into bladder. From reference 16, with permission.

allow for resorption/organization of the pelvic hematoma. As this occurs, the bladder and prostate will descend toward a more dependent position within the pelvis. The ultimate size of the PFUDD will depend on the size of the initial hematoma but will generally be less than 3 cm in the majority of cases.¹ Perineal anastomotic repair is successful in more than 90% of cases and is the preferred approach to delayed repair of the PFUDD even in the longest of defects. An abdominal-perineal repair may be indicated when complex pathology, such as bladder neck abnormalities, recto-urethral or vesicourethral fistulae, coexist with the PFUDD. Some continue to advocate abdominal-perineal or transpubic approaches for long defects. Endoscopic approaches have been described and may be successful in highly select cases with minimal defects.

To estimate the length of the defect and to plan the operative approach, a retrograde urethrogram and simultaneous antegrade cystourethrogram (via the suprapubic tube) are obtained (Figure 53.2). In order to precisely size the defect, the patient must be able to mount a detrusor contraction to open the bladder neck and allow for flow of contrast to the point of obliteration. Since in the clinic setting this will only be possible in 75% of cases,⁴ intraoperative cystourethrogram or antegrade cystoscopy can be performed to supplement the preoperative findings. Since the majority of defects will be less than 3 cm and since a perineal tension-free anastomosis is achievable with defects as long as 10 cm,⁴ routine use of these intraoperative diagnostics will rarely alter the planned operative approach and can usually be omitted.

Complicating factors such as the presence of bladder stones or urethral fistulae are also identifiable on this



Figure 53.2 A combined cystogram and retrograde urethrogram in a patient with an obliterative posterior urethral stricture. This study identifies a short obliterative segment that was amenable to a perineal anastomotic urethroplasty utilizing only the first of the four sequential maneuvers (distal urethral mobilization) to accomplish a tension-free anastomosis. The posterior urethra fills down to the obstruction; however, earlier in the study, a competent bladder neck was noted.

‘up and down-o-gram’ and can be addressed at the time of repair. Bladder neck competency should also be assessed at this time, as severe incompetence may predict incontinence after a successful PFUDD repair.²¹

Magnetic resonance imaging (MRI) can measure the length of a PFUDD to within 5 mm accuracy.²² Coronal and sagittal imaging give a three-dimensional assessment of prostatic dislocation and can be used to plan the operative approach. MRI, however, is limited in its ability to image fistulous tracts, identify persistent extravasation, and assess bladder neck competency and therefore should not be used as a sole diagnostic modality.^{22–24}

Perineal anastomotic urethroplasty

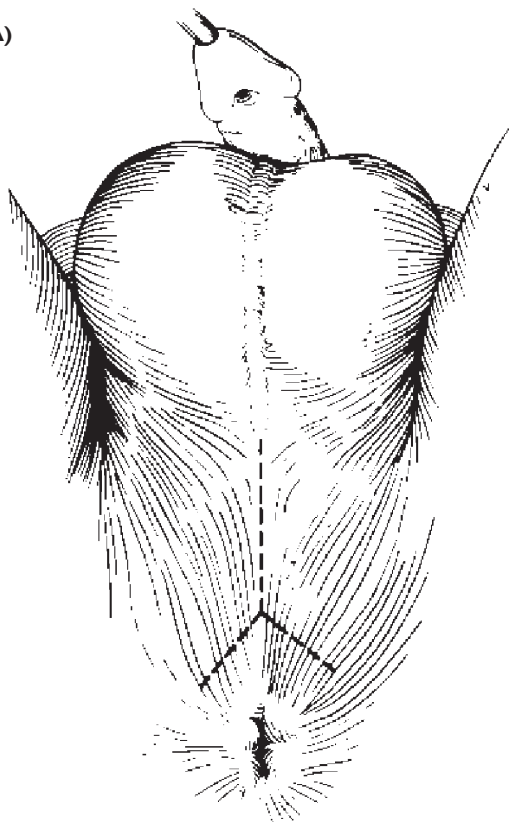
With the patient in a moderate lithotomy position, a perineal incision is made down to the bulbospongiosus

muscle which is incised in the midline and reflected from the underlying bulbar urethra. The perineal tendon is also taken down. A perineal Book-Walter or Omni retractor greatly facilitates exposure. The bulbar urethra is circumferentially mobilized from the level of the suspensory ligament of the penis proximally to the point of urethral obliteration as identified by the retrograde passage of a 20 Fr catheter and the urethra is then transected through the scar proximal to this point. The bulbar arteries are often encountered lateral to this point, if they have not already been devitalized by the initial injury, and can be suture ligated. Because the cavernous nerves are located in close proximity lateral to the membranous urethra bilaterally, excessive dissection, manipulation, and cautery in this area should be avoided. A 20 Fr Van Buren sound is advanced via the suprapubic tract through the bladder neck down to the proximal limit of the urethral obliteration where, if the defect is not too long, its tip can be palpated from the perineal side of the dissection. A scalpel is used to cut down onto the tip of the sound giving perineal access to the normal prostate-membranous urethra above. Scar tissue is minimally excised to adequately expose healthy prostate-membranous urothelium. Complete excision of all scar tissue is both unnecessary and potentially damaging to the cavernous nerves.

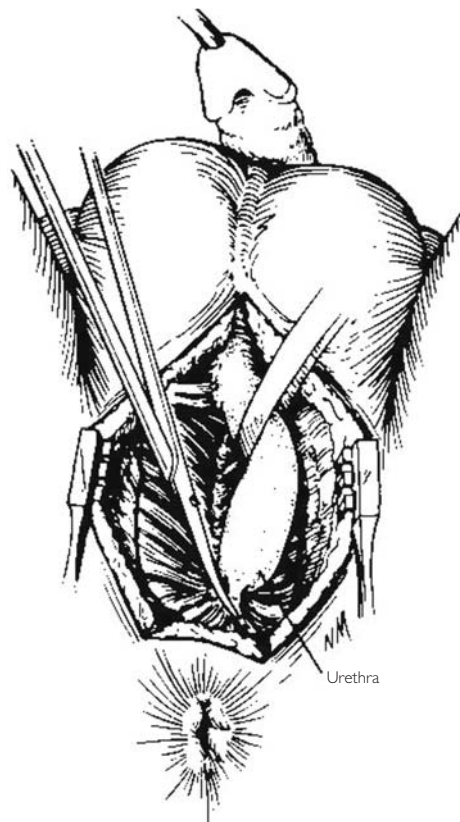
At this juncture, the first of four sequential maneuvers to ensure a tension-free anastomosis is initiated (Figure 53.3). These well-defined steps are carried out in ordered progression until a tension-free reapproximation of the mobilized bulbar urethra to the posteriorly spatulated prostato-membranous urethra can be accomplished. For short defects the first step alone may suffice whereas longer defects may warrant progressing through all four maneuvers. As popularized by Webster and Ramon,²⁵ these sequential maneuvers enable repair of defects as long as 10 cm. The sequential maneuvers are as follows.

- Step 1 The distal urethra can be circumferentially mobilized as far distally as the suspensory ligament of the penis, beyond which the risk of penile retraction or chordee increases. Between 2 and 3 cm of length can be gained with distal urethral mobilization alone.
- Step 2 The corporal bodies can be separated starting at the crus and continuing distally for a distance of 4–5 cm. This is accomplished by scissor separation in the midline between the corporal bodies where there is a predictable avascular plane. The distal urethra can then be situated between the corporal bodies, which decreases the ‘travel distance’ to the anastomosis.

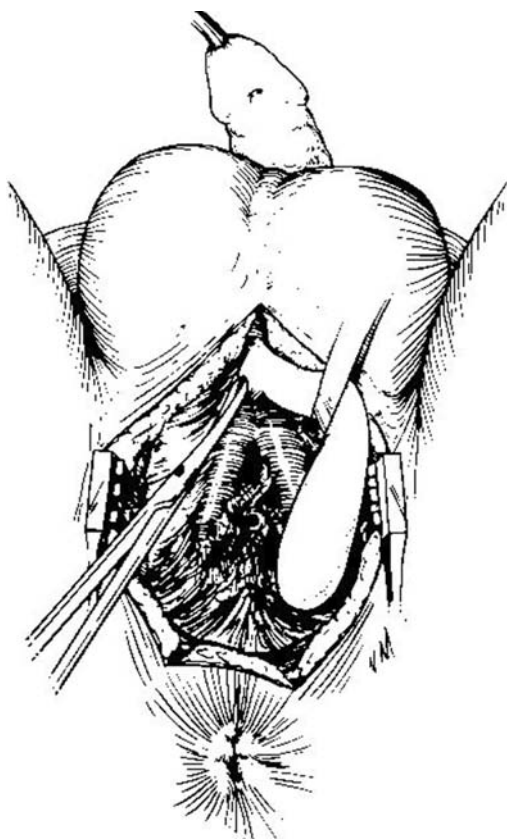
(A)



(B)



(C)



(D)

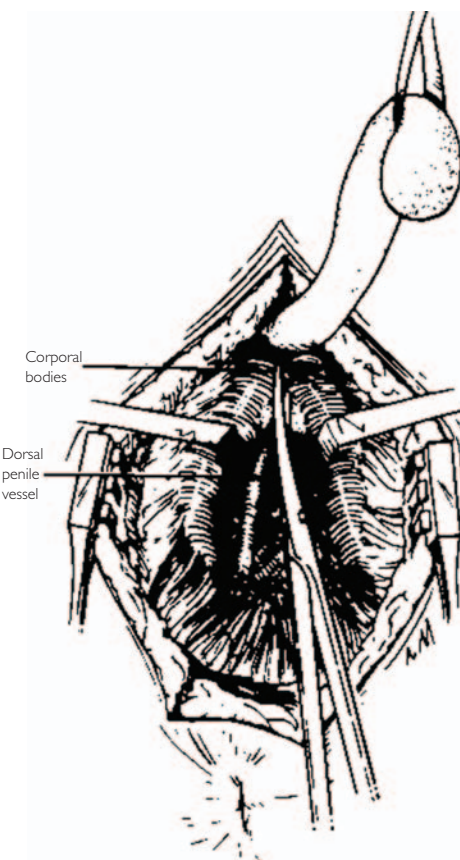


Figure 53.3 (Continued)

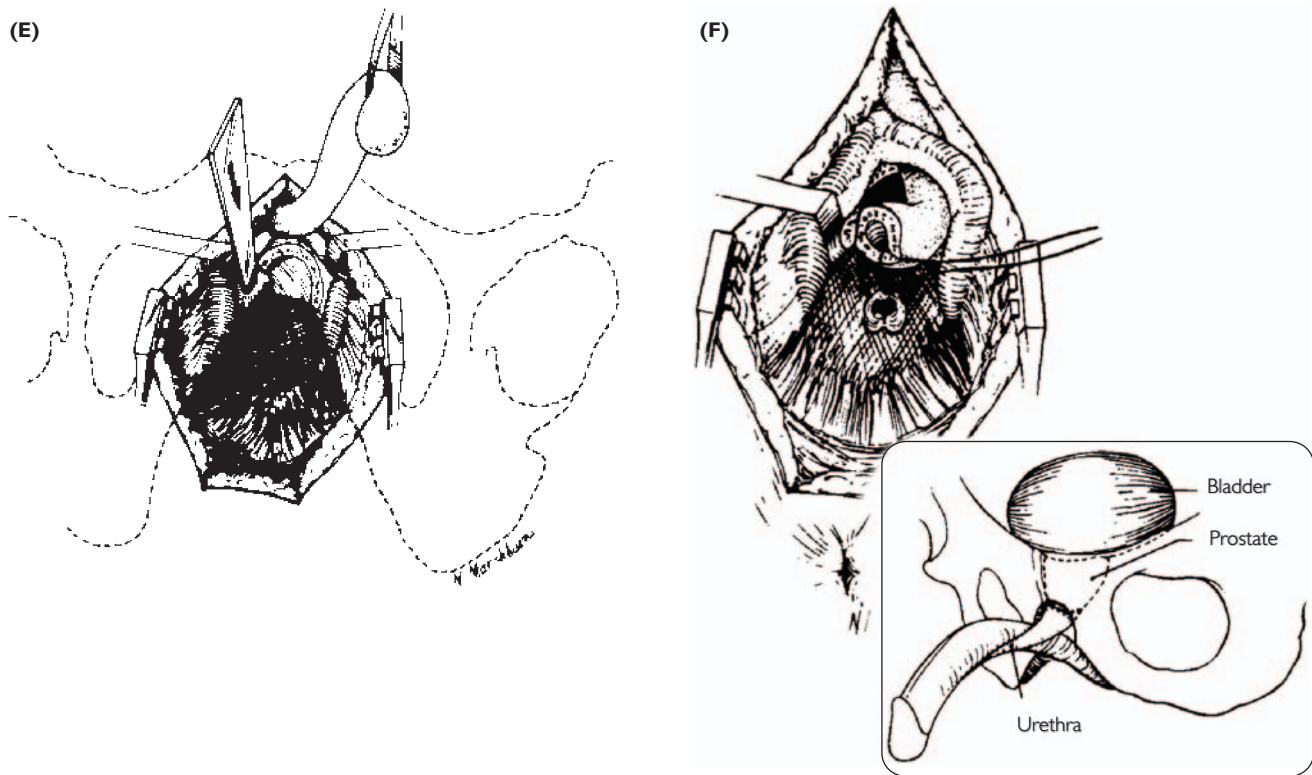


Figure 53.3 Perineal repair of pelvic fracture urethral distraction defect. (A) The urethra is accessed via a perineal 'Mercedes-Benz' incision. (B) The urethra is circumferentially mobilized and released from its posterior attachments to the perineal body. (C) The urethra is transected at the level of the stricture and then dissected distally as far as the suspensory ligament of the penis. (D) The corporal bodies are separated for approximately 5 cm beginning at the crus distally, exposing the dorsal penile vessels and inferior surface of the pubis. (E) The undersurface of the pubis can be excised with an osteotome or bone rongeur. The urethra will now course between the separated corporal bodies and through the bony defect to the prostatic apex, considerably shortening the distance. (F) To further shorten the distance to the prostatic apex, the mobilized distal urethra can be re-routed around a corporal body and through the bony defect. This final step will allow for a tension-free anastomosis in difficult cases with long defects.

Step 3 Once the corporal bodies are separated, the inferior portion of the pubis will be exposed. To further shorten the travel distance, a 2 cm wedge of bone is excised from the undersurface of the pubic bone. Since the urethra normally traverses under (caudal to) the pubic bone, segmental inferior pubectomy shortens this path toward the membranous urethra.

Step 4 If the distal urethra does not adequately reach for anastomosis despite executing steps 1–3, the urethra can be re-routed around one of the corporal bodies. This 'supra-crural' re-routing is accomplished by extending the bony defect in the pubis under the corporal body to one or other side, thereby creating a tunnel through which the urethra can travel around the lateral surface of the corporal body. Care must be taken to avoid dissection directly on the dorsal surface of the corpora in order to avoid injury to the cavernous nerves.

At the authors' institution the first two steps alone were sufficient for a tension-free anastomosis in approximately 50% of cases, with supra-crural re-routing necessary in only 23%. Recent reports from experienced centers have found the initial steps sufficient in the overwhelming majority and progression to corporal re-routing quite rare.^{15,26} This varied use of the advanced steps may reflect different patient characteristics (shorter defect lengths) or a willingness to mobilize the urethra more distally or to accept increased anastomotic tension.

Once it is ensured that a tension-free approximation of the urethral ends is possible, the anastomosis is performed using 4-0 or 5-0 absorbable interrupted sutures. A long nasal speculum inserted into the proximal urethra will aid visualization of the prostatic urethral mucosa margins and facilitate suture placement. Sutures are placed in the proximal urethral end beginning at the 12 o'clock position and continued in a clockwise direction. Each suture is inserted into a corresponding position in the distal urethra

and tied in the exact order in which they were placed. Fashioning the needle into a J-shape greatly assists suture placement through the proximal urethra from outside to inside. Once the anastomosis is completed a 12 Fr Foley catheter is inserted and the bulbospongiosus muscle is reapproximated, followed by Colles' fascia and the perineal skin. We do not routinely place drains. Both a suprapubic tube and 12 Fr urethral Foley catheter remain in place for 3 weeks. Once a peri-catheter RUG excludes extravasation, the urethral catheter can be removed followed shortly thereafter by the suprapubic tube, contingent on a successful voiding trial.

Using this sequential strategy, a one-stage perineal anastomotic urethroplasty will repair even the longest of PFUDDs, without re-stricture or further intervention, in more than 90% of cases.^{4,13–15} When strictures reform they usually occur at the anastomosis and are frequently salvageable with endoscopic urethrotomy or self dilatation.⁴ The rare patient will require a secondary urethroplasty (1/109 patients at the authors' institution).⁴ ED after urethroplasty is generally the result of the initial injury and new onset ED arises in less than 5% of patients. As discussed above, postoperative continence relies on the presence of a competent bladder neck. In the absence of concomitant bladder neck injury, previous bladder neck surgery or bladder overactivity (an uninhibited detrusor contraction will funnel open the bladder neck), continence should be expected after perineal urethroplasty.

Abdominoperineal repair

The overwhelming majority of PFUDDs can be repaired successfully through the perineum and, as noted earlier, length of the defect alone should not preclude a perineal approach as defects as long as 10 cm are amenable to repair. Early endoscopic realignment of a severe urethral disruption with a large hematoma, even if it does not ultimately result in a stricture-free patent urethra, can shorten the defect and facilitate a later one-stage perineal urethroplasty.¹⁵ However, there are a number of complex situations which may warrant an abdominoperineal posterior urethroplasty.

Bladder neck incompetence Since the bladder neck is often the sole continence mechanism after PFUDD injuries, if the bladder neck appears incompetent on preoperative cystogram and scarred on cystoscopy, there is a substantial risk for post-repair incontinence. Through an abdominal incision the bladder neck can be repaired and dissected free from the surrounding fibrosis at the time of urethroplasty, to provide for a viable

continence mechanism. Alternatively, as is our preference, a perineal urethroplasty can be performed with the intent of performing a staged bladder neck repair should incontinence declare itself postoperatively. Since the degree of bladder neck incompetence is difficult to precisely quantify and because its mere presence does not always predict incontinence, a significant percentage of patients will indeed be continent despite the preoperative appearance of the bladder neck.²¹

Fistula and chronic periurethral cavity Rarely, a periurethral cavity formed from a liquefied pelvic hematoma can epithelialize and communicate with the urethra at the site of the disruption. Perineal exposure alone may not provide sufficient exposure to address these lesions. Similarly, when the PFUDD is complicated by fistulization to the rectum or bladder, abdominoperineal exposure will enable excision of the fistulous tract and fortification of the repair with an omental pedicle or even diverting colostomy, if necessary.

Abdominoperineal posterior urethroplasty The procedure, including positioning the patient in the lithotomy position in padded Allen stirrups, commences in the same fashion as the perineal urethroplasty. The perineal dissection is similarly performed and the urethra is transected at the level of the obliteration. The anterior urethra is mobilized and length progressively obtained via the progressive steps as outlined above. After inferior pubectomy, a midline subumbilical abdominal incision is made and the retropubic space is entered and dissected to the prostatic apex until communication with the perineal dissection is established. We prefer to open the bladder high on the anterior wall to aid in the retropubic dissection by using the surgeon's finger to identify and avoid injury to the bladder neck. As originally described by Waterhouse et al a complete anterior pubectomy was performed using a Gigli saw.²⁷ This maneuver destabilized the pelvic ring and was supplanted with a technique in which only partial removal of the posterior surface of the pubis was performed, using a Capener's gouge, as described by Turner-Warwick.²⁸ The combined pubis excisions from the perineal and abdominal sides, will provide sufficient pelvic floor exposure to enable both a tension-free urethral anastomosis and correction of the associated injuries. An omental flap is then mobilized to cover the anastomosis, buttress fistula repairs, and to obliterate periurethral dead-space. If circumstances dictate that the peritoneal cavity be avoided, gracilis (Angermeier comment in Pratap et al),²⁹ cremasteric or dartos muscle flaps (Pratap) have been described,²⁹ as extraperitoneal alternatives to omentum interposition.

Endoscopic repair

Many different endoscopic approaches to the PFUDD have been described. In contradistinction to endoscopic urethral realignment soon after injury as we discussed earlier, delayed endoscopic repair involves creating a channel through the established scar tissue (rather than across the hematoma) between the urethral ends. Cold knife, electrocautery, and an array of laser systems have all been used to cut through the scar tissue and re-establish urethral continuity over a catheter. Re-stricture rates are likely to be in the order of 40–50% and the retreatment rates for re-stricture are high.^{1,30} Since results are inferior to open urethroplasty, endoscopic 'core-through',³⁰ should be reserved for select cases with a very short PFUDD or when perineal urethroplasty is contraindicated (e.g. positioning restrictions). It must be accepted that 'success' is a stable stricture which will often require self dilatation for maintenance of lumen. Urolume stenting of such scar-lined defects is notoriously unsuccessful with predictable scar ingrowth of the stent lumen.

SUMMARY

Initial management of a posterior urethral injury will often be dictated by the magnitude of associated injuries and the patient's overall medical condition. Initial urinary diversion with a suprapubic tube and delayed management of the resulting PFUDD is always an acceptable strategy, particularly in an unstable patient with multiple injuries. Once the patient has been stabilized, we believe that an endoscopic attempt at delayed primary re-alignment (days after the initial injury) should be considered. At a minimum, delayed realignment over a catheter may shorten the ultimate length of the PFUDD thereby facilitating a perineal urethroplasty, and at best may promote complete urethral healing without the need for further repair. Regardless of initial management decision, a one-stage perineal urethroplasty will successfully repair the overwhelming majority of pelvic fracture urethral distraction defects. A combined abdominoperineal posterior urethroplasty should be reserved for select complex cases such as those PFUDDs associated with periurethral cavities or with previous anterior urethral stricture disease that will prohibit distal urethral mobilization. Utilizing the progressive stepwise approach, success rates of greater than 95% should be expected after perineal urethroplasty even with the longest of urethral defects.

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54 Anterior urethral reconstruction: excision with primary anastomosis

Michael B Williams and Steven M Schlossberg

HISTORICAL PERSPECTIVE

Historically, the reconstructive ladder approach to urethral stricture disease has long been held. This consists of performing the simplest operation first, and, if this step fails, repeating it or progressing to the next most complex procedure. The root of this method can be traced back to R Hamilton Russell who stated in the *British Journal of Surgery* in 1914:¹

Excision of the stricture has never been very generally practiced, and is only attempted in only a small minority of cases: the reason is that the operation . . . is difficult and uncertain in its results . . . This is so well recognized by surgeons of experience in this class of work, that they urge great pains should be taken to obviate the perineal open operation.

Dr Russell went on to describe his experience with several cases of excision with primary anastomosis (EPA) of the anterior urethra. His technique varied from the one used today with the utilization of a strip anastomosis. By 1919, he had compiled 31 patients of which he reported long-term follow-up on 15 with two failures.² One point he emphasized remains true today:

The whole thickness of the corpus spongiosum [around the strictured area] must be removed.

Over the past century, modern urethral reconstruction has progressed rapidly to the point that the ladder concept is quite antiquated. While there remain indications to perform dilatations and internal urethrotomy, EPA has become a mainstay for those patients seeking cure from short segment anterior stricture disease involving spongiofibrosis.

EVIDENCE FOR EXCISION WITH PRIMARY ANASTOMOSIS

Over the past century, dilatation and internal urethrotomy have been the most utilized procedures in terms of surgical ‘correction’ of anterior strictures. More

recently, this has progressed to EPA due to the significant failure rate with utilization of direct vision internal urethrotomy (DVIU) and dilatation along with the excellent results for cure with the anastomotic urethroplasty.

The majority of the literature defines DVIU and dilatation with short-term success, but significant failure rates in the long term. Heyns et al, via a prospectively randomized trial in 210 men, found that if a patient had a single urethrotomy or dilatation and did not re-stricture in the initial 3 months, then the success rate was approximately 60% at 4 years. However, if a second or third procedure had to be performed, this number dropped to 0% at 48 months.³ Additionally, complications from DVIU have been reported to be quite common and include bleeding, sepsis, and incontinence,⁴ with new impotence and rectal perforation being rare complications.⁵

With regard to EPA, Santucci et al retrospectively reviewed 168 consecutive anastomotic urethroplasties, and, with a minimum follow-up of 6 months, a 95% success rate was noted.⁶ Success was defined as not requiring further operative intervention to include dilatation, internal urethrotomy, or urethroplasty. Radiographic follow-up included a voiding cystourethrogram once the catheter was removed and a retrograde urethrogram at 3 and 12 months. Additionally, flow rates were obtained at 3, 6, and 12 months postoperatively. Six of the eight recurrences found were within the first year postoperatively. Five patients were managed with DVIU and three with repeat urethroplasty. Noted perioperative complications occurred in 6% of patients and included transient thigh numbness, small wound dehiscence, erectile dysfunction, catheter dislodgement, and wound infection. It should be noted that the majority of the strictures that were repaired were less than 2 cm, although some strictures were repaired up to 4.5 cm with excellent results.

We recently retrospectively reviewed 260 consecutive patients who had a bulbar stricture and EPA over the preceding 20 years.⁷ Stricture length was similar to that reported by Santucci et al, in that the mean length was 1.9 cm with six patients having a stricture length

greater than 3.5 cm. After a mean follow-up of 50 months (range 6–122 months) and 25% with a minimum of 5 years in follow-up, a success rate of 98.8% was noted. Again, success was defined as no further need for operative intervention. Voiding cystourethrogram was performed at 3 weeks and urethroscopy was performed at 6 months. Stricture recurrence was noted in three patients with two of them occurring within the first year postoperatively. New erectile dysfunction was demonstrated in six patients with four of these patients having had significant straddle trauma. Of note, 39% of the 260 patients had previous failed attempts of dilatation, DVIU, or both prior to formal EPA. Further, three different surgeons with similar surgical principles comprised the study population.

EPA has also been found to be efficacious in the pediatric population. Rourke et al evaluated 17 consecutive open urethroplasties in patients under 17 years of age.⁸ EPA was performed on six of these with a mean stricture length of 1.4 cm. Though a small population, none of the patients required further operative intervention. Voiding cystourethrogram was performed at 3 weeks with urethroscopy at 6 months. Mean follow-up was 67 months for the entire cohort (range 13–130 months).

Specifically with regard to straddle injuries, Park and McAninch retrospectively evaluated 78 patients with documented blunt trauma to the perineum.⁹ Of the patients 40% presented immediately following the injury while the remainder presented 6 months to 10 years later. Of note, stricture length was significantly longer with delayed presentation. Of the patients 72% had EPA with two failures noted in patients who had prior urethral manipulation with DVIU.

With regard to stricture length, Morey and Kizer evaluated the morphometric reasons for successful EPA repair in strictures of length more than 2.5 cm.¹⁰ Twenty-two patients of 250 consecutive urethral reconstructions received EPA for proximal bulbar stricture. Of these, 11 patients had stricture length greater than 2.5 cm. Mean follow-up was 22 months with ten of 11 patients being successful. Reasons found to be a cause for success included isolated solitary stricture to the proximal bulbar region with the proximal extent being within 1 cm of the membranous urethra; good vascularity; and quality of the corpus spongiosum. It was also suggested that patients with a stretched penile length of more than 14 cm were more amenable to EPA, although this was not evaluated as part of the study.

It has been recently suggested via abstract that ventral buccal mucosal onlay urethroplasty (BMG)¹¹ should be utilized for the primary repair of short proximal bulbar

strictures. Twenty-eight patients underwent EPA with 19 having formal BMG urethroplasty. The mean stricture length was 1.4 cm, however, the longest stricture was 3 cm. Two patients failed EPA with mean follow-up of 36 months for the entire cohort. Failures were not identified as to stricture length or cause, which may have been secondary to patient selection for EPA rather than failure of the procedure. We still recommend that EPA is the primary treatment for proximal anterior urethral strictures less than 2 cm.

Finally, with regard to healthcare cost, Rourke and Jordan demonstrated that treatment with immediate open urethral reconstruction for stricture length of less than 2 cm was more cost effective than DVIU.¹² Taking into account the successful long-term rate for DVIU as 30%, electing to proceed with the DVIU approach for strictures had an actuarial cost of 17 747 US dollars as compared with open urethroplasty as an initial operative repair of 16 444 US dollars.

EVALUATION FOR EXCISION WITH PRIMARY ANASTOMOSIS

As per standard practice, evaluation for urethral stricture must be of the entire urethra and determination should be made of the location, length, depth, and density of the strictured segment. When considering a patient for EPA, the location and length of the stricture is of utmost importance. The stricture should not be more proximal than the membranous sphincter or more distal than the suspensory ligament. If considering EPA with a penile stricture more distal than the ligament, the ideal patient is someone who is not sexually active as mobilization beyond the suspensory ligament will likely result in ventral penile curvature. Stricture length should be maintained less than 2 cm in most cases, although some exceptions can be made.¹⁰ Normally evaluation for length can be accomplished with a retrograde urethrogram and a voiding urethrogram; however, it may require evaluation with endoscopy in both antegrade (via suprapubic cystostomy) and retrograde fashions. In those patients with a narrow caliber stricture, evaluation with a pediatric cystoscope can allow for visualization through the strictured area without dilatation, thus avoiding scar contraction. Importantly, the surgeon correcting the stricture disease should be the individual responsible for performance of these studies.

The urethrogram should be performed in a steep lateral oblique so as to not underestimate the length of the involved segment. If urethral dilatation or instrumentation has recently been performed, it is

important to allow time for scar contraction prior to radiographic evaluation of the urethra so as to not underestimate the segment length. The waiting period is patient dependent, however, the re-stricturing will reoccur by 8–12 weeks. An adequate retrograde urethrogram demonstrates the entire urethra including the prostate and bladder neck.

POSITIONING

It has been our practice to utilize exaggerated high lithotomy with boot stirrups for urethral reconstructive surgery. Several key principles should be emphasized, as neurologic sequelae are quite common if not properly positioned. Feet should be firmly seated within the boots and maintained in a neutral position so as not to stress the common peroneal nerve and produce foot drop. Straps should be applied with adequate padding so as not to compress the sensory nerve on the dorsal aspect of the foot. When raised into lithotomy, the boot should suspend the foot without undue pressure on the lower aspect of the leg and with the minimum amount of flexion to hips and knees. We prefer additional padding to the lower back secondary to the significant pressure to this region during the operative case. Further, this will elevate the perineum to facilitate dissection. Finally, every effort should be made to limit the amount of time in exaggerated lithotomy to less than 5 hours. Beyond this time period, Anema et al found complications of rhabdomyolysis, neuropraxia, and compartment syndrome to be significantly elevated.¹³

INSTRUMENTS

It is important to note that EPA requires special instrumentation not normally utilized in the routine urologic surgery. As with all reconstruction, the primary focus is to minimize tissue trauma by emphasizing delicate dissection techniques. For exposure during EPA, we have utilized both the Bookwalter perineal retractor and a modified Denis-Browne ring retractor that will permit placement of stay hooks for exposure during EPA. Fine tenotomy scissors and fine forceps, such as plaques and Browns, are essential during dissection and anastomosis. Additionally, bougie a boulé allow for accurate sizing of the urethra for anastomosis after spatulation as well as aid in initial dissection at the distal aspect of the stricture. A flexible cystoscope is also useful in evaluating the proximal urethra prior to anastomosis.

TECHNIQUE

The perineal dissection begins with identification of the ischial tuberosities, median raphe of the perineum, and perineal body. A midline inverted-Y incision is made with the lateral incisions medial to the tuberosities. Colles' fascia is then exposed in the midline and developed until entering the superficial perineal space and identifying the midline fusion of the ischiocavernosus musculature. It is then carried toward the scrotum where the corpus spongiosum is visualized. At this point, the Bookwalter perineal retractor is placed and exposure of the ischiocavernosus muscle is divided to reveal the bulbospongiosus muscle and corpus spongiosum.

Removal of the entire stricture as well as the spongiofibrosis circumferentially is of utmost importance. Three underlying technical points should be made involving EPA (Figure 54.1):

- Total excision of the fibrotic area
- Widely spatulated urethral anastomosis
- Tension-free anastomosis.

The goal of dissection is to mobilize the urethra circumferentially, with proximal dissection to the bulb and distal dissection to the level of the penopubic ligament. Initially, the bulbospongiosus muscle is split in the midline and then retracted laterally. The bulb is dissected in an anterior fashion with care to stay close to the crus of the corporal cavernosa. The corpus spongiosum is then detached from the cavernosum and triangular ligament laterally is followed by release of the bulbospongiosum from the perineal body posteriorly (Figure 54.2). If mobilization is performed in this manner, the arteries of the bulb will remain intact.

One always notes significant difficulty with mobilization in the region of the stricture secondary to spongiofibrosis. In order to maintain accurate tissue planes and facilitate dissection, begin at the distal aspect of the stricture. Pass a bougie a boulé through the distal urethra to the level of the stricture to allow for identification of the proximal endpoint. Once this aspect is circumferentially mobilized, utilize a vessel loop for retraction and continue dissection proximally with care to stay dorsally on the cavernosal bodies. This will allow further development of the intercrural space without entering the spongiosum.

Once mobilization is complete, pass the bougie to the level of the distal extent of the stricture. Care should be taken to not push the bougie against the stricture. Rather, let it rest at its distal extent. Utilizing a 15-blade scalpel, incise onto the bougie and enter the

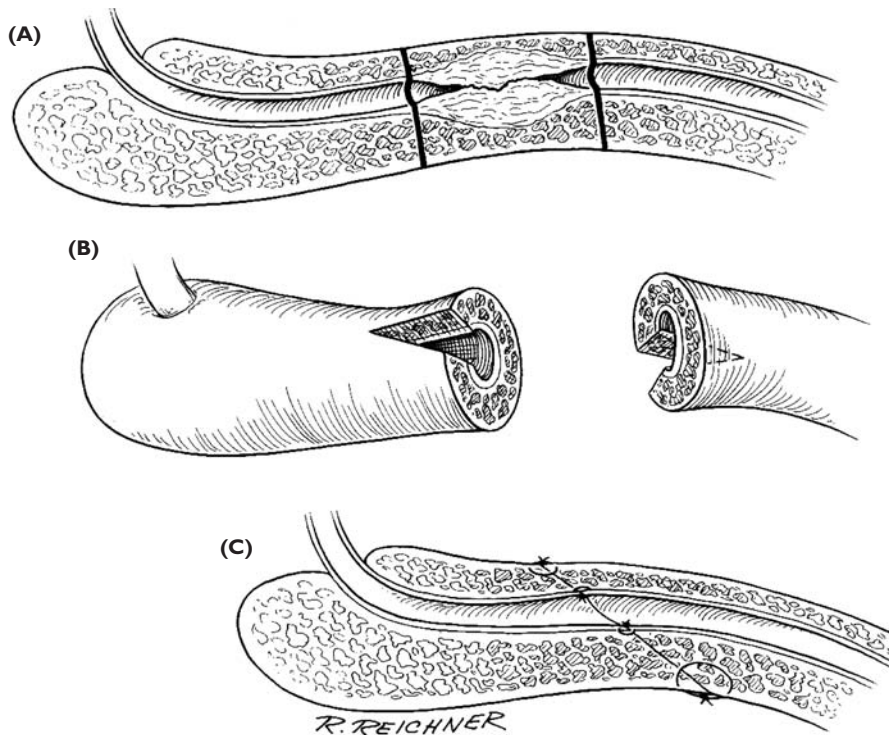


Figure 54.1 The key principles of EPA. (A) Removal of the entire diseased segment. (B). Wide spatulation of the proximal and distal segments. (C) Tension-free anastomosis. From reference 14, with permission.

urethra. The stricture is then transversely incised at its most proximal and distal aspects.

Spatulation of the proximal anterior urethra is then performed (Figure 54.1B). We prefer spatulation to be dorsal to allow a 32 Fr bougie to pass easily. At this point, the cystoscope is utilized to evaluate the urethra proximal to the strictured site to ensure a healthy appearance as well as identification of the membranous sphincter. Placement of approximately ten anastomotic 3-0 long-term absorbable sutures is performed, all of which are tagged in order to facilitate ease of identification for placement in the distal urethral segment. Attention is then directed to the distal segment, which is then spatulated in a ventral aspect to allow a 30–32 Fr bougie to pass easily (Figure 54.1B). The anastomotic sutures are then placed in sequential order through this segment and tagged. The sutures are tied beginning at opposite locations laterally and moving dorsally. Once this is performed, placement of a 14 Fr soft urethral catheter is facilitated through the anastomosis and the retention balloon is inflated. The remainder of the ventral sutures are then tied (Figure 54.1C).

Closure of the wound begins with the reapproximation of the bulbospongiosus musculature in the midline. It is then followed by interrupted approximation of the ischiocavernosus musculature and Colles' fascia. Realignment of the perineal body is followed by

subcutaneous running suture. The skin is then reapproximated in a running fashion. Small suction drains are placed deep and superficial to the ischiocavernosus and Colles' closures.

For short segment strictures (less than 2 cm) the above description should easily allow for a tension-free anastomosis. In general, the need for additional mobilization is secondary to very proximal bulbar to membranous urethral strictures. Separation of the corporal bodies in the midline approximately 4–5 cm via incision of the triangular ligament will allow for significant mobilization toward the membranous aspect of the urethra.

POSTOPERATIVE MANAGEMENT

Patients will remain on intravenous antibiotic therapy for approximately 48 hours with subsequent removal of the small suction drains over that time period. The urethral catheter will remain for approximately 3 weeks followed by a voiding trial. The suprapubic cystostomy tube will be removed after passage of the voiding trial.

It is now our routine to have patients return at 6 months for cystoscopic evaluation of the anastomotic site. They are requested to return for evaluation if there are any subsequent issues.

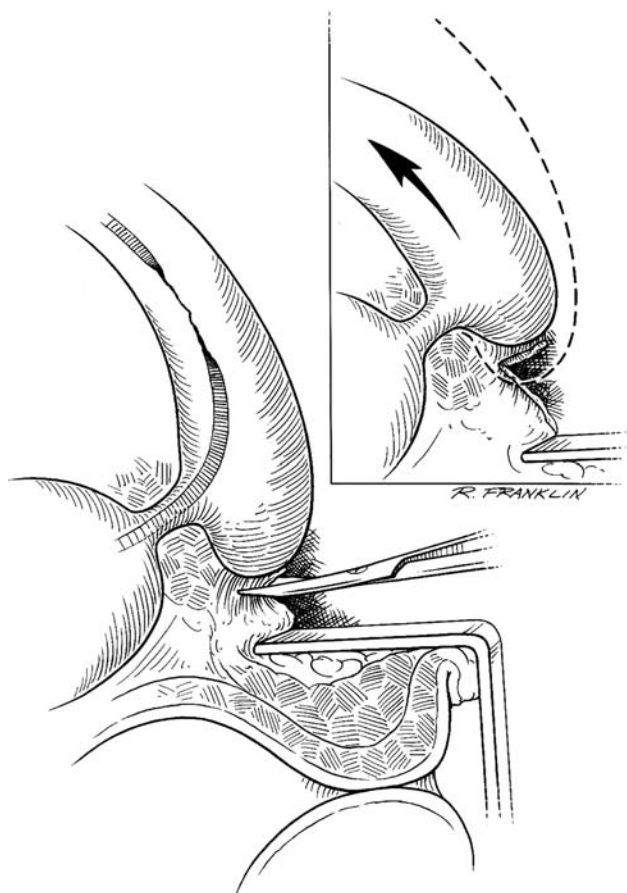


Figure 54.2 Release of the attachment from the posterior bulbospongiosus muscle to the perineal body. This maneuver allows for increased mobilization of the proximal segment to facilitate a tension-free anastomosis without sacrificing the arteries to the bulb. When combined with development of the intercrural space, this can yield up to 1.5 cm of length. From reference 14, with permission.

COMPLICATIONS

Complications from EPA are primarily limited to the effects of exaggerated high lithotomy, the primary complication being transient neuropraxia of the lower extremity. Anema et al reported a complication rate of 8% in 185 patients undergoing open urethroplasty.¹² However, further complications of severe neuropraxia, rhabdomyolysis, compartment syndrome, and calf hematoma were also noted. Further, when the lithotomy time exceeded 5 hours duration, the risk of mild and severe complications increased to 23% and 5%, respectively.

In order to reduce the increased risk of the above complications, the following preventive measures are recommended: limiting lithotomy time to under 5 hours; additional padding to the lower back; ensuring the

hips and knees are not in excessive flexion; and ensuring the foot is not in dorsiflexion. It is clearly demonstrated that positioning of the patient for exaggerated high lithotomy is of significance for successful outcomes. Interestingly, no thromboembolic complications were identified.

NEW INNOVATIONS

Jordan et al have recently reported a technique of vessel sparing EPA for proximal bulbous urethral strictures in ten patients.¹⁵ The primary goal is to maintain the vascular supply to the bulb by dissection of the bulbar arteries from the urethra in a ventral fashion. The rationale for applying this technique is to assess its ability to decrease the possibility for vasculature loss as has been traditionally found in the standard proximal bulbar EPA. Of the 11 patients who have undergone this procedure, three of the patients had undergone radical prostatectomy and were incontinent. With a mean follow-up of 12.5 months (range 6–38), all patients have patent urethras as assessed by cystoscopic examination. In the radical prostatectomy patient with anterior urethral stricture and incontinence, this technique may be of benefit in maintaining the vascular supply to the bulb, thus decreasing the incidence of cuff erosion in those undergoing artificial urethral sphincter placement.

CONCLUSION

Excision and primary anastomosis is an excellent curative procedure for short segment anterior urethral strictures. Though most strictures that are repaired via this technique are less than 2 cm, in the selected population, it has been extended successfully to 5 cm. Attention must be paid to the preoperative radiographic evaluation. Additionally, proper care in placement of the patient into exaggerated high lithotomy will limit complications. In the end, EPA offers a success rate unmatched by other interventions with few complications when performed by the experienced reconstructive surgeon.

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55 Anterior urethral reconstruction: ventral grafts

Kenneth W Angermeier

INTRODUCTION

The first contemporary series of adult patients undergoing anterior urethral reconstruction using buccal mucosa (BM) was reported by El-Kasaby et al in 1993.¹ The grafts were placed ventrally in both the penile and bulbous urethra with a success rate of 90%. Since that time, the use of BM for urethral reconstruction has expanded greatly, and currently it is the material of choice for substitution urethroplasty. A number of series have demonstrated success rates of 87–90% using ventral grafts with very acceptable associated morbidity.^{2–4} In 1998, Barbagli et al⁵ introduced the concept of dorsal BM graft placement during urethral reconstruction, and some authors hypothesized that this approach might result in superior results compared with ventral grafting. It has become clear over time, however, that both techniques provide similar excellent outcomes and it has been this author's opinion that the two procedures are complementary and should be selected based upon stricture location and the condition of the corpus spongiosum at the time of surgery.

PATIENT EVALUATION

In evaluating the patient with a recurrent urethral stricture, it is important to determine the location and extent of the stricture, and to estimate the depth of associated spongiofibrosis or density. Dynamic retrograde urethrography (RUG), voiding urethrography (VU), and endoscopy are the primary means of assessing these parameters. Endoscopy is used to confirm the radiographic findings, and to examine the urethral mucosa and associated scar visually. Although advocated by some, we have not found that ultrasound or magnetic resonance imaging adds significant information to the above. Direct palpation of the urethra may be helpful in assessing spongiofibrosis. A thorough examination of the genital skin is important to identify areas with adequate vascularity that may serve as a pedicled skin island if needed.

GENERAL CONSIDERATIONS

Open urethral reconstruction is the procedure of choice for urethral strictures associated with dense spongiofibrosis or other factors suggesting that direct vision internal urethrotomy (DVIU) will not be effective. These may include stricture length of more than 1 cm, penile or penoscrotal location, presence of multiple strictures,⁶ and greater than 75% narrowing of the strictured urethral lumen as measured on RUG.⁷ Urethral reconstruction is also indicated when more conservative forms of treatment such as internal urethrotomy or dilatation have failed. It is important to allow the urethra to be free of instrumentation for approximately 3 months prior to urethral reconstruction in order to allow the stricture to fully declare itself and be 'at its worst' at the time of repair so it is not underestimated. If a patient cannot make it for 3 months without obstructing, a suprapubic catheter is placed. There are a variety of surgical techniques available to the reconstructive surgeon depending on stricture length, location, and density. Excision with primary urethral anastomosis (EPA) is the optimal method of urethral reconstruction when feasible. Its use, however, is generally limited to strictures within the bulbous urethra that are 2.5–3 cm in length due to constraints on urethral mobilization and extensibility. Strictures that cannot be reconstructed by EPA require substitution urethroplasty. In this technique, a urethrotomy incision is made through the stricture and into healthy urethra proximally and distally. Tissue in the form of a graft or a flap is then transferred into the resulting urethral defect in order to re-establish urethral continuity. As noted previously, BM has emerged as the most commonly used and effective material for substitution urethroplasty. BM has a thick, non-keratinized epithelium that makes it easy to handle and suture. The thin, richly vascularized lamina propria leads to excellent graft take and the donor site morbidity is very acceptable. In addition, it is a 'moist' epithelium and this may also have favorable implications for long-term success.

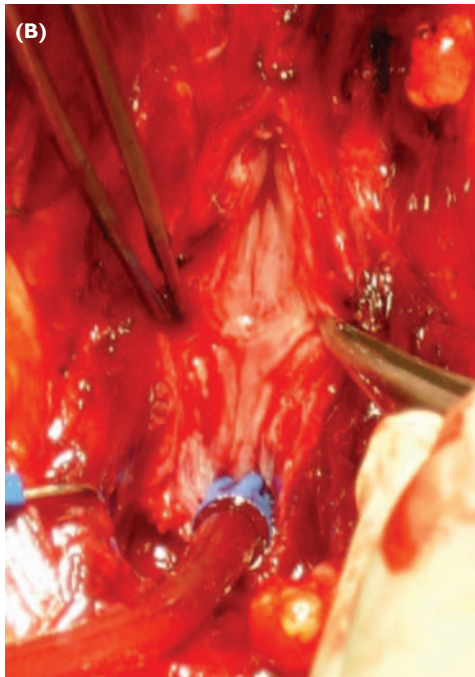


Figure 55.1 (A) A bougie is passed to identify the distal end of the stricture. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved. (B) Completed ventral urethrotomy.

BULBOUS URETHRAL RECONSTRUCTION

Although it can be done in other locations, the ideal candidate for a ventral BM onlay graft repair is a patient with a bulbous urethral stricture more than 3 cm in length and a fairly healthy corpus spongiosum sufficient to allow closure over the graft. The surgical procedure begins with placement of the patient into exaggerated lithotomy position using boot-type stirrups. This author elevates the buttocks on a specially made thick gel pad to aid exposure and ensure that there are no undue pressure points and that the buttocks and thighs are soft and comfortable. All patients are given subcutaneous heparin preoperatively.

A modified lambda incision is made in the perineum and dissection proceeds to the level of the bulbospongiosus muscle using electrocautery and scissors. The corpus spongiosum is identified just distal to the muscle and the muscle is divided in the midline to fully expose the bulb of the corpus spongiosum. A modified Denis-Browne retractor is used for exposure. The urethra does not have to be mobilized off the corporal bodies, but this author does dissect the corpus spongiosum free laterally on each side to the dorsal midline attachments to aid its later closure. Posterior and lateral attachments to the proximal bulb may be taken down if needed, taking care not to compromise the bulbar arteries. A 24 or 26 Fr bougie is inserted to define the distal end of the stricture, and a ventral urethrotomy incision is created onto the bougie (Figure 55.1). The urethrotomy is continued with tenotomy scissors proximally through the stricture and for at least 1 cm into healthy urethra such that a 26–30 Fr bougie is accepted in both directions. Flexible cystoscopy is performed to confirm that there is no additional stricture. The length of the defect is measured, and attention is turned to the inner cheek.

Exposure is gained with a self-retaining oral retractor and a small additional blade to retract the tongue medially. A facelift retractor is used on the side of the lip. Stenson's duct is identified opposite the second upper molar and avoided during the dissection. The rectangular graft is marked and we infiltrate underneath it with 0.5% lidocaine with epinephrine to aid hemostasis. The border of the graft is incised and it is then elevated off the underlying muscle with tenotomy scissors. The graft is placed in saline, and meticulous hemostasis is obtained using electrocautery (Figure 55.2). A dry sponge is left on the donor site until the end of the case. We have

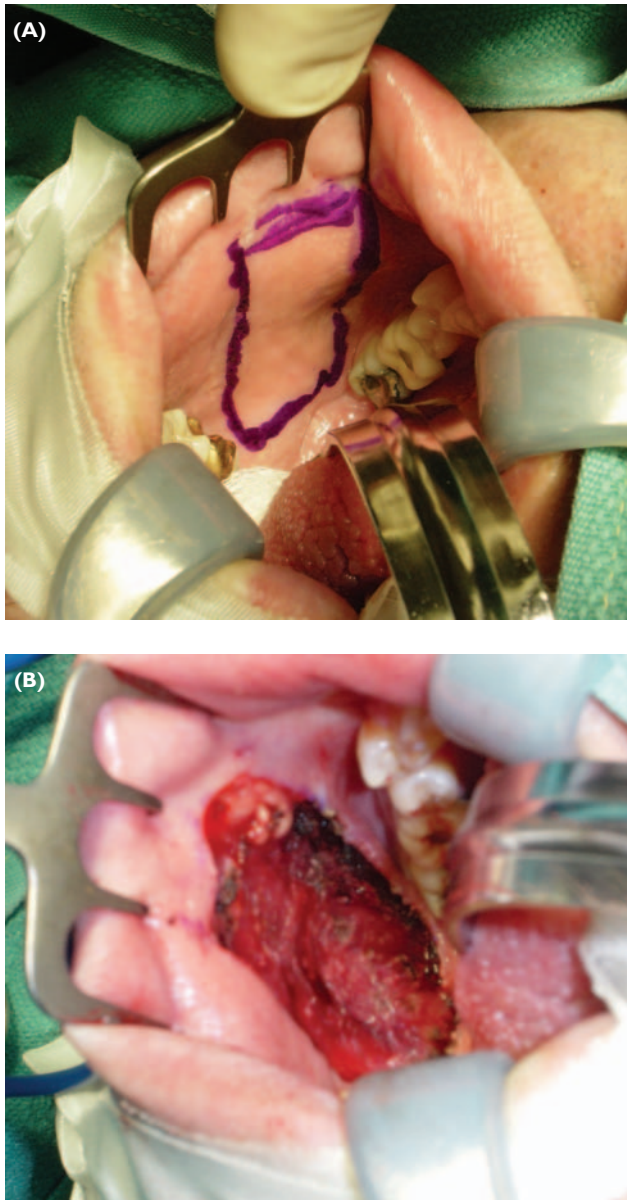


Figure 55.2 (A) Buccal mucosa graft marked. (B) Buccal graft donor site left open to heal by secondary intention.

never closed the donor site and have not seen any significant problems in doing so, and this approach has been supported by other studies.⁸ The graft is thinned and tailored when necessary, but the rectangular shape is maintained to help avoid narrowing at the apices when it is sutured into place. When greater length is needed, the harvest can be performed in the shape of a trapezoid (wider near the lip) extending beyond the mandibular ridge posteriorly. The BM graft is then reconfigured by excising a triangular segment from the wider distal

portion and suturing it to the thinner proximal segment with 5-0 chromic, resulting in increased length with adequate overall width of 2–2.5 cm.

The graft is then sutured to the urethral mucosa distally and proximally using five to seven interrupted sutures of 5-0 PDS with the epithelial surface facing inward toward the lumen. The lateral closure is then carried out using running 5-0 PDS in a watertight fashion (Figure 55.3). The corpus spongiosum is then closed over the top of the graft (spongioplasty) using running 4-0 PDS. This is an essential step for a ventral graft procedure, and if the corpus spongiosum is deficient, dorsal graft placement should be considered. An 18 Fr soft silicone catheter is inserted and a small suction drain is placed in the periurethral region. The bulbospongiosus muscle is closed in the midline using interrupted 3-0 Vicryl sutures. A 7 mm suction drain is placed in the perineum overlying the muscle, and Colles' fascia is closed using running 3-0 Vicryl, followed by skin closure with running 4-0 chromic. A clear adhesive dressing is placed over the incision and drain sites, and the patient is placed supine. Except in unusual circumstances, a diverting suprapubic catheter is placed percutaneously at the end of the case using the urethral catheter to fill the bladder. The urethral catheter is then plugged and taped to the lower abdomen without tension.

AUGMENTED ANASTOMOTIC URETHROPLASTY

It is not uncommon for a lengthy bulbous urethral stricture to have an area that is more narrow and dense than the remainder of the stricture. This may at times represent an initial short stricture that has been instrumented multiple times leading to adjacent wider caliber stricture from manipulative trauma (Figure 55.4). In this setting, it seems to be advantageous to excise the dense narrow stricture and to anastomose the urethra dorsally to improve the urethral plate, shorten the length of graft needed and optimize the corpus spongiosum.⁹ This excision can be done partial thickness or full thickness. After exposing the corpus spongiosum as described for a standard ventral graft urethroplasty, a ventral urethrotomy is made. One then observes the urethral plate to see if there is an area of particular narrowing or scar that would be amenable to excision. If the area is 1 cm or less in length and not associated with full-thickness spongiotfibrosis, the urethral mucosa and the scarred underlying spongiosum can be excised partial thickness leaving some healthy spongiosum in

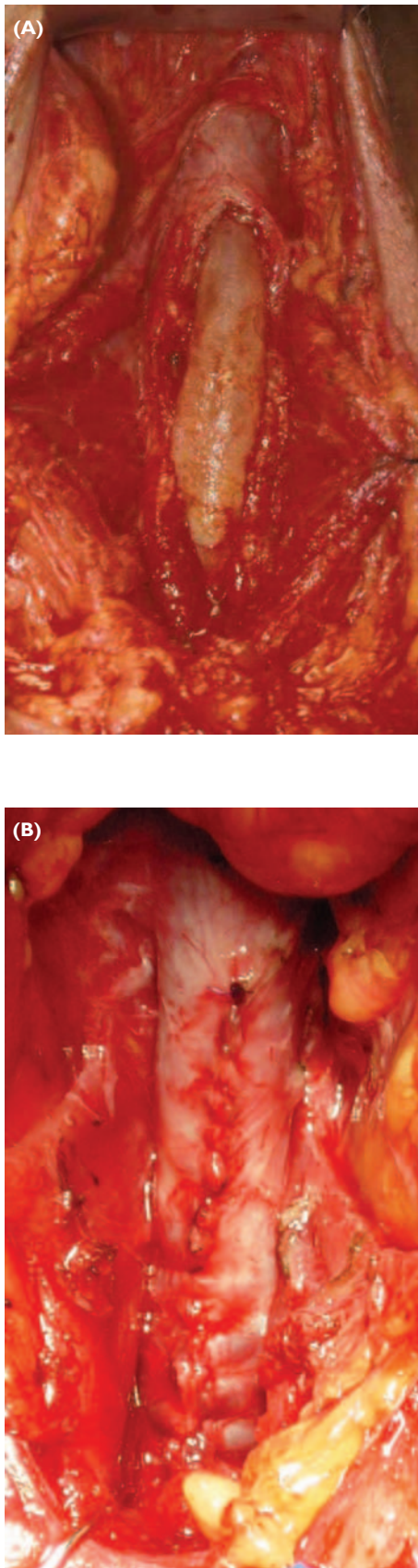


Figure 55.3 (A) Buccal mucosa graft sutured into the urethrotomy defect. (B) Corpus spongiosum closed over the top of the graft.

place. The urethral mucosa is sutured together dorsally using interrupted sutures of 5-0 PDS with the knots buried, and the BM graft is then sutured in place. If the narrowed portion is longer or there is full-thickness spongiofibrosis, the urethra is fully mobilized off the corporal bodies from the suspensory ligament distally to the departure of the urethra from the bulb proximally. Posterior midline attachments of the bulb to the central tendon complex may be taken down to aid proximal urethral mobility, but care must be taken not to divide the bulbar arteries. The strictured urethral segment is then excised full thickness. Buck's fascia is dissected off the distal urethra if needed to aid extensibility and the space between the corporal bodies may be developed as well if needed. Dorsal wall anastomosis is conducted using interrupted 4-0 PDS posteriorly, initially in one layer near the midline and then converting to a two-layer closure as one proceeds laterally with 4-0 PDS on the spongiosum and 5-0 PDS on the urethral mucosa. The remainder of the repair proceeds as described previously (Figure 55.5). Following spongioplasty, the proximal urethral segment may be advanced distally a little and tacked to the adjacent tunica albuginea of the corporal bodies to fix the urethra in place and take further tension off the anastomosis. A recent study documented a success rate of 91% using this technique for recurrent bulbous urethral strictures.¹⁰

PENILE URETHRAL RECONSTRUCTION

Although the first choice for a reconstruction of a penile urethral stricture is often an island flap repair,¹¹ a ventral BM onlay graft can be used if there is insufficient penile skin for a flap (Figure 55.6). This does not apply to patients with lichen sclerosis or to adults with complications of previous hypospadias repair in whom a staged urethroplasty is favored. With the patient supine, a ventral midline penile incision is made and carried through the glans penis if necessary. The urethrotomy is continued proximally through the stricture and at least 1 cm into healthy urethra. Glans wings are developed sufficiently to allow them to be brought around the reconstruction with a urethral meatus of at least 22–24 Fr in caliber. An appropriate BM graft is harvested and sutured to the urethral edge using a few interrupted 5-0 PDS sutures proximally and running 5-0 PDS laterally. The deep layer of the glans is re-approximated using interrupted 4-0 PDS. The urethral meatus is sutured using interrupted 4-0 or 5-0 chromic and the remaining glans is closed in the

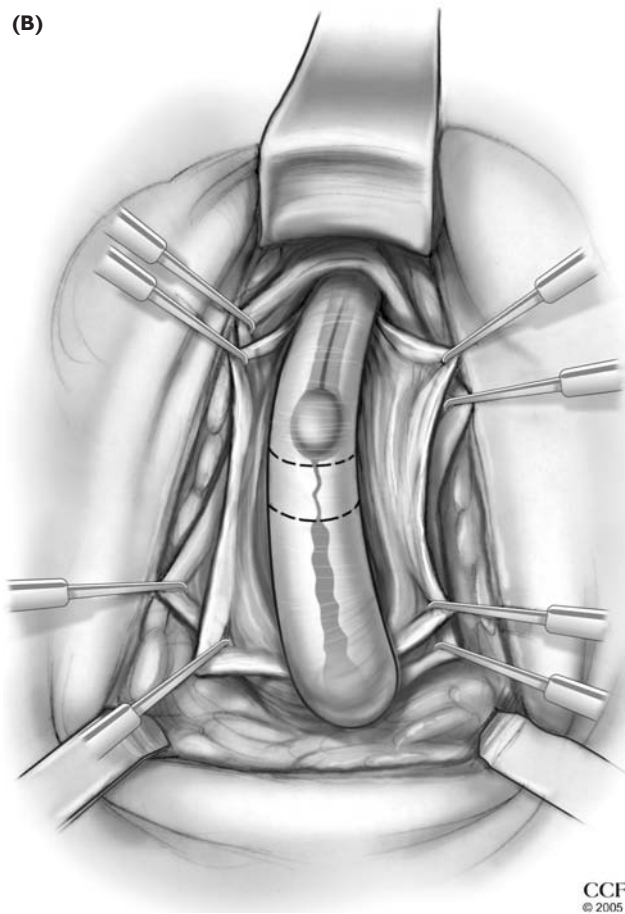


Figure 55.4 (A) Retrograde urethrogram demonstrating bulbous stricture with a short dense area amenable to excision (bracket). (B) Bougie identifies the distal end of the stricture prior to excision of the narrow segment. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

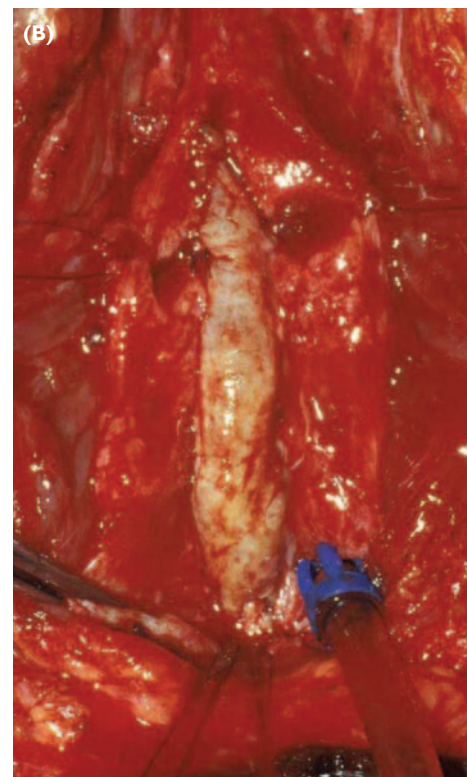
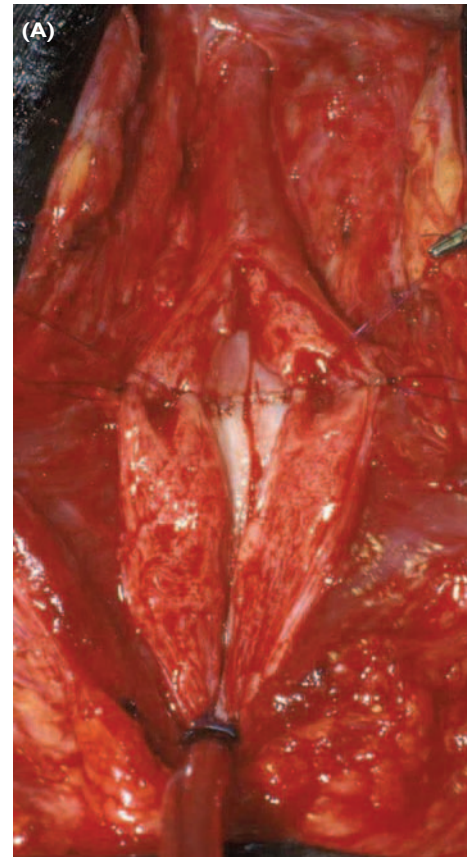


Figure 55.5 (A) Completed dorsal urethral anastomosis. (B) Buccal mucosa graft sutured into the urethrotomy defect prior to spongioplasty.

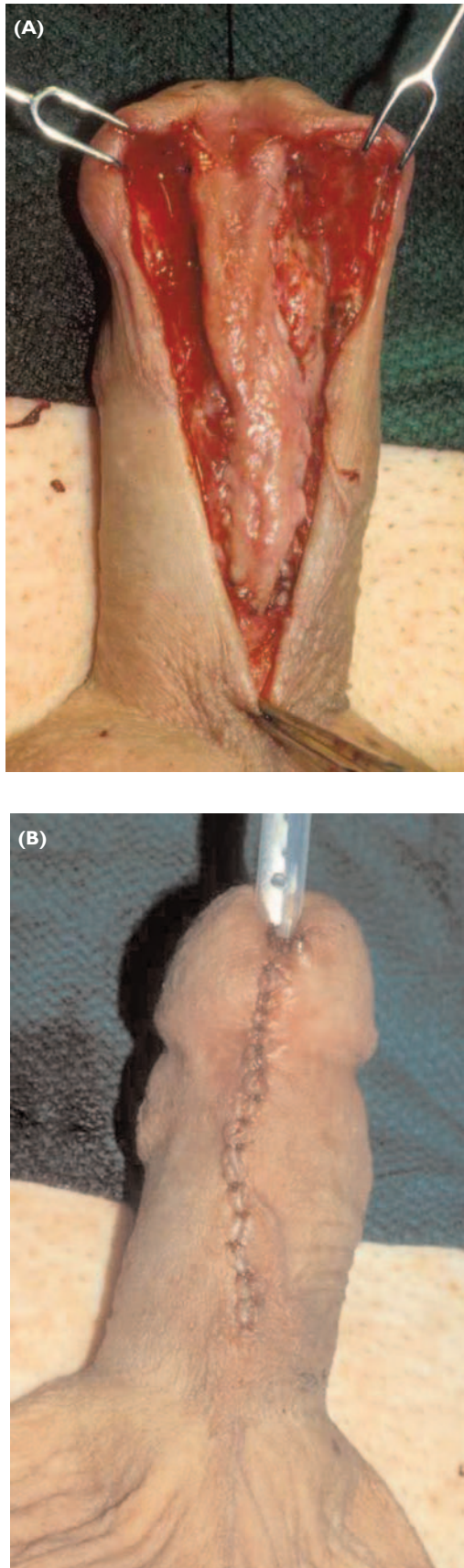


Figure 55.6 (A) Buccal graft sutured into penile urethrotomy defect. (B) Completed repair.

same fashion. Proximal to the glans it is not possible to perform a spongioplasty, and therefore the overlying dartos fascia is quilted to the graft laterally using 4-0 or 5-0 chromic every 1 cm, and with the interrupted 4-0 PDS used to close the dartos fascia in the midline. The skin is closed using interrupted 4-0 chromic and a urethral stent is placed through the repair and sutured to the glans penis. For the stent, this author fenestrates a soft silicone catheter cut off at both ends to an appropriate length. A diverting suprapubic catheter is placed and a clear adhesive dressing is placed around the penis.

PANURETHRAL STRICTURES

Panurethral strictures are defined as those that extensively involve the penile and bulbous urethra. One approach used in these situations is the combination of a proximal ventral BM graft and a distal penile or penoscrotal island flap.¹² In this technique, the procedure starts in the exaggerated lithotomy position and a standard ventral BM onlay graft procedure is done through a perineal incision. After completion of the urethral work and without closing the incision, the patient is repositioned into low lithotomy for the remainder of the procedure. This is an important step to minimize the chance of a positioning related complication as these procedures can be of long duration. When the penile skin is free of disease, we have most commonly used a longitudinal penile or penoscrotal island flap based on the lateral dartos fascia for the distal reconstruction. The skin island is then sutured to the distal end of the buccal graft repair with interrupted 4-0 or 5-0 PDS, being sure to include both the ventral BM and the overlying corpus spongiosum in the sutures. The skin island is secured distally, and lateral closure is done using running 5-0 PDS. A 16 Fr soft silicone catheter is placed as well as a suprapubic catheter for urinary diversion.

POSTOPERATIVE CARE

While in the hospital, patients are maintained on intravenous antibiotics. An antibiotic mouthwash is given four times per day and they are placed on a soft diet for a few days. Prophylactic subcutaneous heparin is administered and pneumatic compression stockings are used. A voiding cystourethrogram (VCUG) is done approximately 3 weeks following surgery. If there is no

extravasation the suprapubic catheter is also removed and a 5-day course of a quinolone antibiotic is prescribed. Flexible cystoscopy is performed at 6 months and 1 year postoperatively. If at 1 year there are any questionable areas felt to be at risk for future narrowing, annual cystoscopy is continued until stability is documented. If the repair is nicely patent at 1 year, patients may follow up with their referring urologist and return as needed.

RESULTS

As noted previously, recently reported success rates for ventral BM graft urethroplasty have ranged from 87 to 91% with minimal morbidity.^{2-4,10} Some urologists currently use dorsally placed grafts in all areas of the urethra for the theoretical advantage of improving graft take and decreasing the incidence of sacculation of the graft. These problems, however, have not been significant in our ventral graft series when used in appropriate patients with closure of the corpus spongiosum over the graft. It seems best to avoid unsupported ventral grafts in the bulbous urethra. Based on this experience, ventral BM graft urethroplasty remains an effective technique for recurrent urethral strictures and is a valuable component of the surgical armamentarium of the reconstructive surgeon.

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56 Anterior urethral reconstruction: dorsal grafts

Guido Barbagli and Massimo Lazzeri

INTRODUCTION

The development of dorsal onlay graft urethroplasty represents a further refinement and evolution of the existing surgical techniques suggested for repair of urethral strictures. In 1979, Devine et al popularized the use of free skin grafts for urethroplasty.¹ In 1980, Monseur described a new urethroplasty that involved opening the dorsal urethral surface and fixing the urethra over the corpora cavernosa, and leaving a catheter in place for a long period of time so as to obtain regeneration of the urethral mucosa.² In 1996, we combined the techniques of Devine and Monseur, and described new penile and bulbar dorsal onlay graft urethroplasties.³ In our techniques the graft is sutured over the albuginea of the corpora and the urethra, fully opened along its dorsal surface, is sutured over the graft. The graft works as an epithelial buried roof-strip facilitating the regeneration of urethral mucosa and thus considerably reducing catheterization time. Moreover, the dorsal buried roof-strip facilitates mucosal regeneration without formation of scar tissue. Restoration of a wide urethra lumen may also be obtained by deep incision of the mucosal urethral plate at the midline and by dorsal inlay placement of the graft. Over time, our techniques have greatly improved and new changes are continuously being suggested.⁴

Buccal mucosa has become an increasingly popular graft tissue for urethral reconstruction in single or multistage procedures as it is easily harvested from the cheek or lip. The use of buccal mucosa avoids any negative aesthetic consequences to the penis since the donor site scar is concealed.⁵ The elasticity and easy handling of the buccal mucosa is superior to penile skin. Moreover, buccal mucosa is hairless, has a thick elastin-rich epithelium, which makes it tough yet easy to handle and a thin and highly vascular lamina propria, which facilitates inosculation and imbibition.⁵

We present here a surgical technique for one-stage penile urethral reconstruction using a dorsal inlay buccal mucosal graft and two surgical techniques for one-stage bulbar urethral reconstruction using dorsal onlay buccal mucosal grafts.

SURGICAL TECHNIQUES

Urine culture, urethrography, sonourethrography, and urethroscopy should be performed preoperatively in the patient with anterior urethral stricture. The patient's clinical history, stricture etiology, and stricture location and length must be carefully examined to better define the characteristics needed in the buccal mucosal graft. Patients who have unresolved infectious disease of the mouth or who have previously undergone surgery of the mandibular arch that prevents the mouth from being opened wide or those who play a wind instrument should be informed that skin will be used for the urethroplasty. In our centers, we generally prefer to harvest the buccal graft from the cheek. However, lip harvesting is preferable when it is impossible to work inside in the mouth, such as when a small, thin graft is needed for meatal or navicularis reconstruction or if the patient has undergone a previous bilateral harvesting from the cheeks making it impossible to obtain a new and sufficient graft from these sites.

Three days prior to surgery, the patient should repeatedly cleanse the mouth with a chlorhexidine mouthwash and continue to do so for the 3 days following surgery. In preparation for surgery, the patient is intubated through the nose, allowing the mouth to be completely free and is draped in two separated parts. Two surgical teams work simultaneously, each team has its own set of surgical instruments. Using a mouth self retractor, only one assistant is needed to harvest the buccal mucosa. The inner mucosal surface of the right cheek is prepared and disinfected, and stay sutures are placed along the external edge of the cheek to keep the buccal mucosa stretched. The Stensen's duct is identified at the level of the second molar and the desired graft size is measured and marked in an ovoid shape. Lidocaine HCl 1% with epinephrine (1:100 000) is injected along the edges of the graft area to enhance hemostasis. The outlined graft is cleanly dissected and removed. The donor site is carefully examined for bleeding and closed with 4-0 polyglactin sutures. When necessary, another graft may be

harvested from the left cheek using the same technique. The graft is stabilized on a silicone board and after careful deflation, is tailored according to site, length, and stricture characteristics. An ice bag is applied to the cheek to avoid pain and hematoma formation.

Basically, the choice of surgical procedure for repairing penile urethral strictures is based on the etiology of the disease. In patients with strictures caused by infection, trauma, instrumentation, or a catheter, the penis is normal and the penile skin, corpus spongiosum, urethral plate, and dartos fascia are available for one-stage urethral reconstruction with a flap or graft. In patients who have experienced a failed hypospadias repair, rendering the penile skin, corpus spongiosum, urethral plate, and dartos fascia unsuitable for one-stage urethral reconstruction, multistage urethroplasty is a possible recommendation. Furthermore, in patients suffering from lichen sclerosus, the use of buccal mucosa as a substitute material is mandatory since as a skin disease, any skin that might be used for the graft is already diseased or may become diseased. Selection of the surgical technique for penile urethroplasty, in addition to respecting the status of the penile tissues and components, must also be based on the proper anatomic characteristics of the penile tissues so as to ensure flap or graft take and survival. Moreover, sexual function is placed at risk by any surgery on the genitalia so dissection must avoid interference with the neurovascular supply to the penis. The use of flaps or grafts should not compromise penile length or cause penile chordee and certainly should not untowardly affect penile appearance. The technique of one-stage penile urethral reconstruction using the dorsal inlay buccal mucosal graft that we describe below fulfills all of these criteria and is simple, reliable, and reproducible in the hands of any surgeon.

Dorsal inlay buccal mucosal graft urethroplasty

A broad spectrum antibiotic is administered intravenously during the procedure and for 3 days afterward. The patient is placed in simple supine position. Methylene blue is injected into the urethra to better define the diseased urethral mucosa and a circumcoronal incision is made completely degloving the penis. The penile urethra is exposed and the strictured tract is fully opened by a ventral midline incision (Figure 56.1). The urethral mucosal plate is longitudinally incised along the midline down to the albuginea of the corpora. The wings of the urethral plate are laterally mobilized

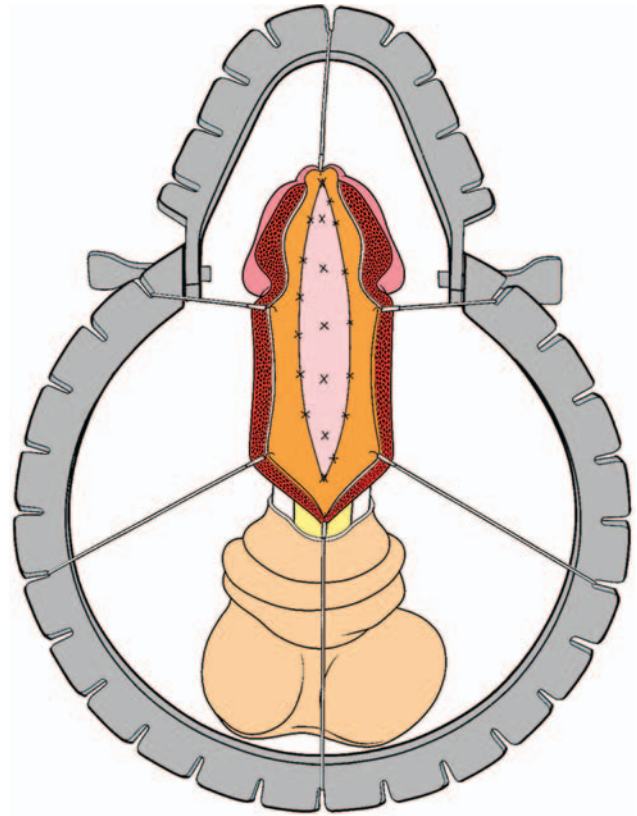


Figure 56.1 The graft is sutured and quilted in the middle of the urethral plate.

to create a wide bed for the graft location. The buccal mucosal graft is sutured and quilted onto the bed of the dorsal urethrotomy using interrupted 6-0 polyglactin sutures (Figure 56.1). The urethra is tubularized up to the glans over a Foley 14 Fr grooved silicone catheter (Figure 56.2). The glans and the penile skin are closed. The catheter is left in place for 2 weeks.

The surgical procedure for the repair of bulbar urethral strictures is selected according to the length and characteristics of the stricture. Strictures ranging from 1 to 2 cm in length are generally treated by using end-to-end anastomosis. Obliterative strictures ranging from 2 to 3 cm in length or strictures that contain a particularly narrow or dense area of 1–2 cm in length are better managed by using augmented roof-strip anastomotic urethroplasty with buccal mucosal graft. Non-oblitative strictures that are longer than 3 cm are treated by using one-stage ventral or dorsal onlay buccal mucosal graft urethroplasty. Finally, strictures associated with local adverse conditions may require a staged urethroplasty. The two techniques of bulbar one-stage dorsal onlay buccal mucosal graft urethroplasty that we describe here are simple, reliable, and reproducible in the hands of any surgeon.

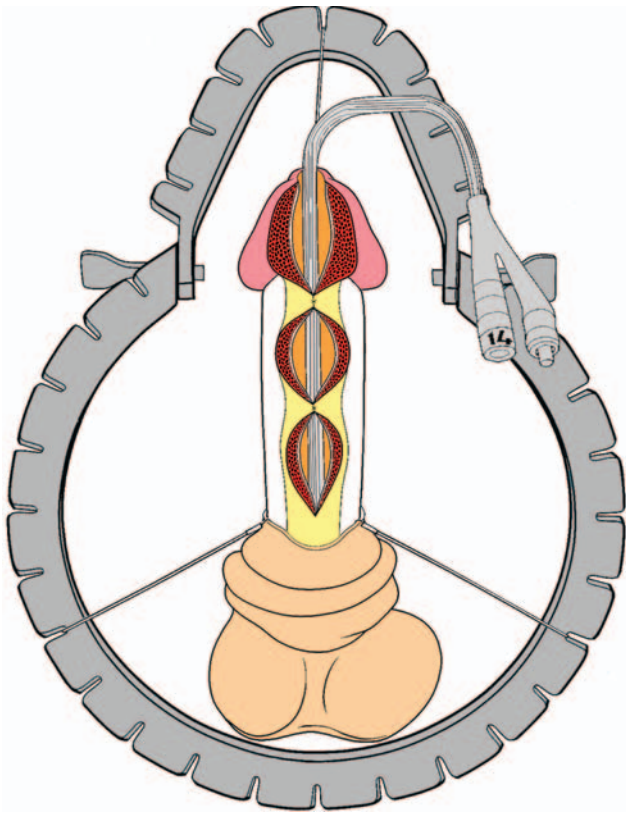


Figure 56.2 The Foley catheter is inserted and the ventral urethral surface is closed.

Bulbar one-stage dorsal onlay buccal mucosal graft urethroplasty

For both techniques, a broad spectrum antibiotic is administered intravenously during the procedure and for 3 days afterward. The patient is placed in simple lithotomy position. The patient's calves are carefully placed in Allen stirrups with sequential inflatable compression sleeves and the lower extremities are then suspended by placement of the patient's feet within the stirrup boots. Proper positioning ensures that there is no pressure on any aspect of the calf muscles and no inward boot rotation, so as to avoid peroneal nerve injury. The skin of the suprapubic region, scrotum, and perineum is shaved and the region is prepared and draped appropriately. Methylene blue is injected into the urethra to better define the diseased urethral mucosa. The midline perineal incision is made and the bulbocavernous muscles are separated.

First technique

The bulbar urethra is dissected from the corpora cavernosa and rotated 180°. The distal extent of the stenosis is identified by inserting a 16 Fr catheter with a round

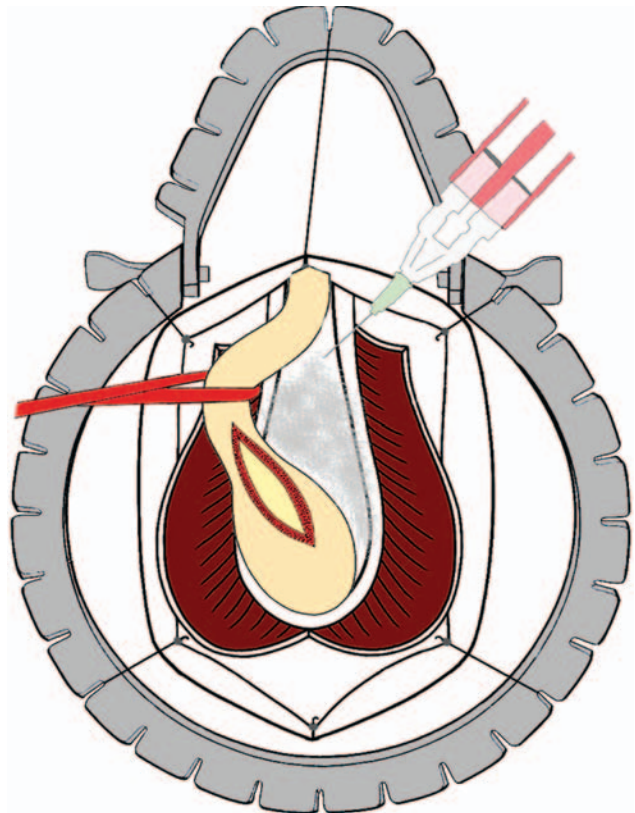


Figure 56.3 The bulbar urethra is rotated 180° and opened along its dorsal surface. Fibrin glue is injected over the albuginea of the corpora cavernosa.

tip up to the point of resistance. The dorsal urethral surface is opened along the midline until the catheter tip and urethral lumen are exposed. The stricture is then incised along its entire length by extending the urethrotomy distally and proximally (Figure 56.3). Once the entire stricture has been incised, distal and proximal calibration of the urethra is mandatory for identifying any residual narrowing. The bulbar urethra is moved to the right side and 2 ml of fibrin glue are injected over the albuginea of the corpora (Figure 56.3). The buccal mucosal graft is then spread fixed over the fibrin glue bed (Figure 56.4). The two apices of the graft are sutured to the proximal and distal apices of the urethrotomy (Figure 56.4). A Foley 16 Fr grooved silicone catheter is inserted. The bulbar urethra is rotated to its original position to cover the graft (Figure 56.5). Three interrupted 4-0 polyglactin sutures for each side are used to stabilize the urethral margins to the corpora over the graft (Figure 56.6). At the end of the procedure, the graft is completely covered by the urethra and 2 ml of fibrin glue are injected over the urethra to prevent urinary leakage (Figure 56.6). The bulbocavernous muscles are sutured and the perineal wound is closed. The catheter is left in place for 2 weeks.

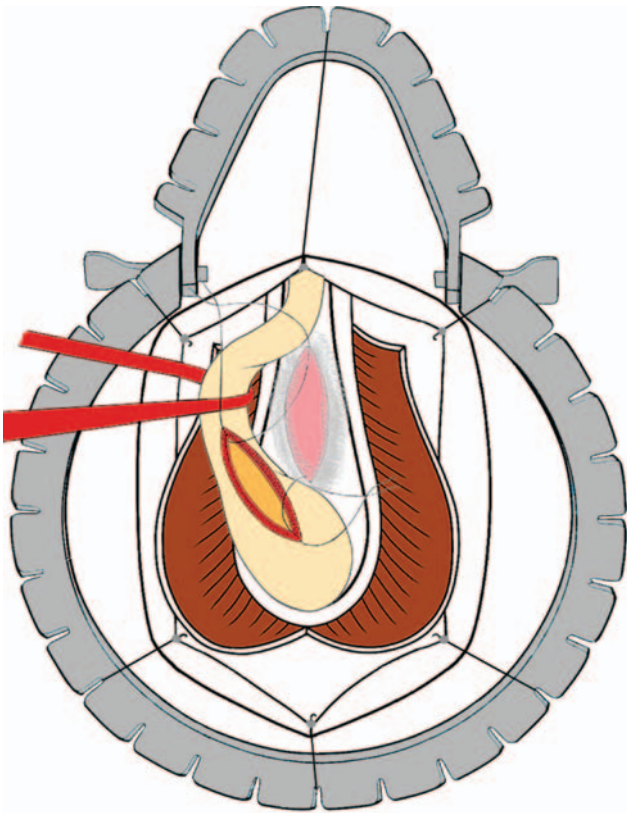


Figure 56.4 The graft is applied over the fibrin glue bed. The apices of the graft are sutured to the apices of the urethrotomy.

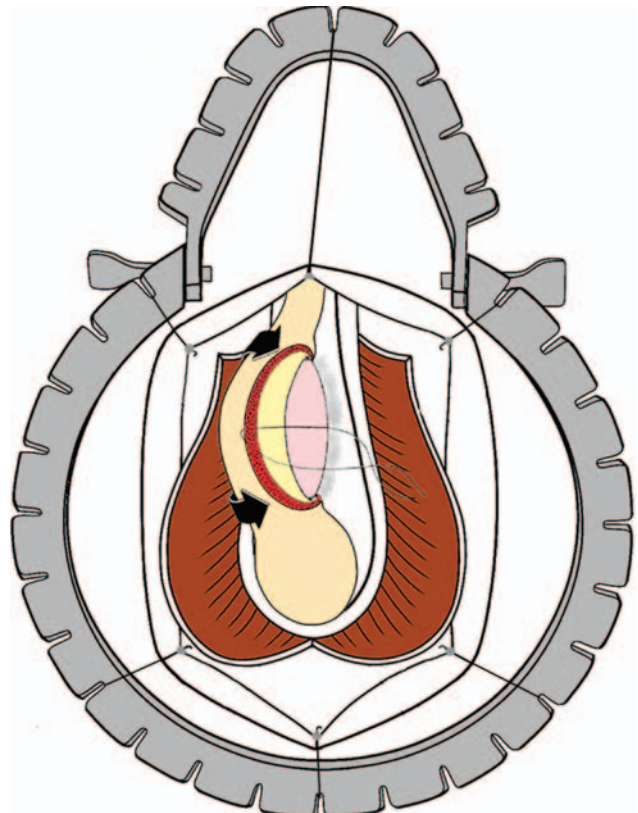


Figure 56.5 The urethra is moved to its original position to completely cover the graft.

Second technique

The distal part of stenosis is identified inserting a 16 Fr catheter with a round tip up to the point of resistance. The urethra is transected at the level of the stricture and the urethral segment involved in the disease is completely removed. The distal and proximal edges of the urethra are longitudinally opened along its dorsal surface (Figure 56.7). Two milliliters of fibrin glue are injected over the albuginea of the corpora cavernosa and the buccal mucosal graft is spread fixed over the fibrin glue bed (Figure 56.7). Three interrupted 5-0 polyglactin sutures for each side are used to stabilize the widely opened distal and proximal urethral mucosal edges to the two apices of the graft (Figure 56.7). The distal urethra is pulled down and stabilized to the left side of the graft (Figure 56.8). The proximal urethra is pulled up and stabilized to the left side of the graft (Figure 56.8). A Foley 16 Fr grooved silicone catheter is inserted and the urethra is rotated back to its original position (Figure 56.9). The right urethral margin is stabilized to the right side of the graft and the distal and proximal urethral edges are sutured together along the midline as in an end-to-end anastomosis (Figure 56.9).

At the end of the procedure, the grafted area is entirely covered by the urethra (Figure 56.10). Two milliliters of fibrin glue are injected over the urethra to prevent urinary leakage (Figure 56.10). The bulbocavernosus muscles are sutured and the perineal wound is closed. The catheter is left in place for 2 weeks.

POSTOPERATIVE CARE

Two ice bags are applied on the genitalia to reduce edema, pain, and hematoma. The patient initially consumes a clear liquid diet and ice cream before advancing to a soft, then regular diet and is discharged from the hospital 3 days after surgery. Two weeks following surgery, the catheter is removed and voiding cystourethrography is obtained. All patients are maintained on oral antibiotics until the catheter is removed. In patients who have undergone penile urethroplasty, early complications include edema, hematoma, and infection. If infection is present and pus discharges from the urethral meatus, the catheter should be immediately removed and a suprapubic cystostomy should be left in place. In addition, the patient should be instructed to

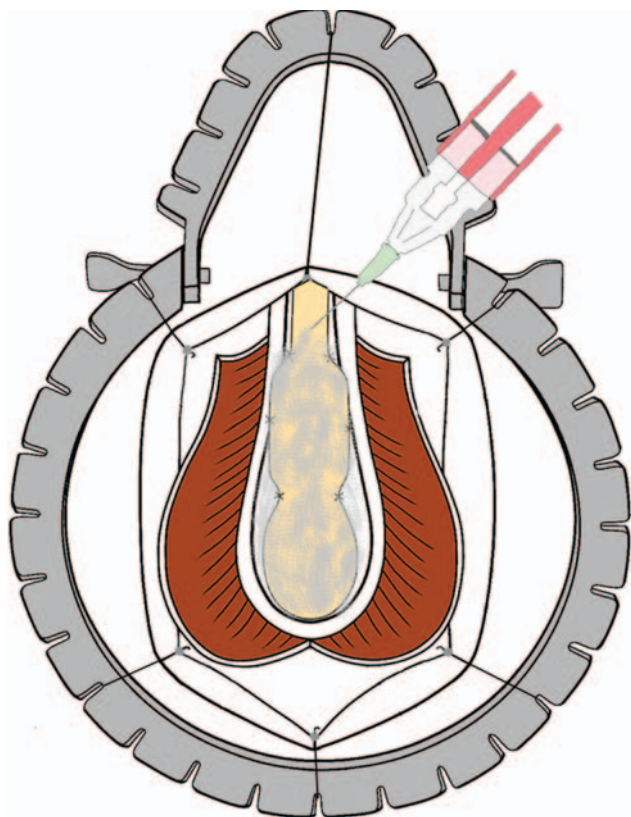


Figure 56.6 Three interrupted sutures for each side are used to stabilize the urethra to the corpora and fibrin glue is injected over the urethra to prevent urinary leakage.

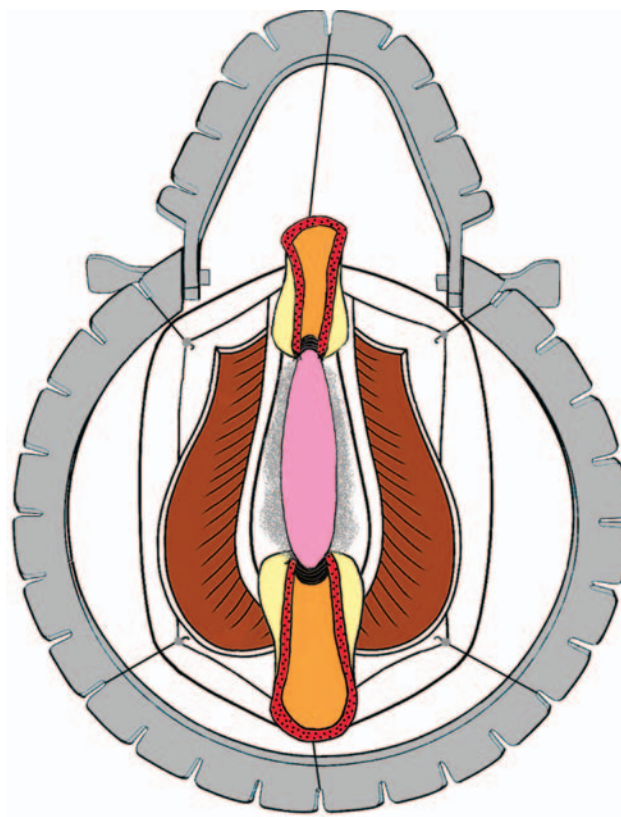


Figure 56.7 The distal and proximal edges of the urethra are opened along its dorsal surface and fibrin glue is injected over the albuginea of the corpora. The graft is fixed over the fibrin glue bed.

void through the new urethra twice daily to wash the pus from it. Unfortunately, patients who experience early complications, such as hematoma and infection, frequently develop major complications such as suture dehiscence, tissue necrosis, and fistula. In patients who have undergone bulbar urethroplasty, an early minor complication is urethrorrhagia due to nocturnal erection. Later minor complications are temporary numbness, dysesthesia to the perineum, and scrotal swelling.

DISCUSSION

The surgical treatment of urethral strictures is continually evolving and since the superiority of one approach over another has not yet been clearly defined, there is renewed controversy over the best means of reconstructing the anterior urethra. The urologist must be fully familiar with the use of both flaps and grafts to deal with any condition of the urethra at the time of surgery.

Buccal mucosa has become the most popular substitute material in the treatment of urethral strictures

and its success has been documented in the numerous series of patients who have already undergone urethral reconstruction. Prior to the use of buccal mucosa, penile skin was the substitute material suggested for anterior urethroplasty. However, is buccal mucosa really superior to penile skin? Alsikafi et al compared the outcome of 95 buccal urethroplasties and 24 penile skin graft urethroplasties in an effort to answer whether buccal mucosa is really the best substitute material and concluded that penile skin and buccal mucosa are both excellent materials for substitution urethroplasty and both have comparable success rates, though penile skin appears to have a longer follow-up.⁶ We retrospectively reviewed 95 patients who underwent bulbar urethra reconstruction.⁷ The strictures were treated using penile skin in 45 cases and buccal mucosa in 50. Thirty-three out of the 45 skin urethroplasties were successful (73%) and 12 (27%) were failures. Forty-two out of the 50 buccal mucosa urethroplasties were successful (84%) and eight (16%) were failures. Thus, skin graft urethroplasty showed a higher failure rate (27%) compared with the buccal

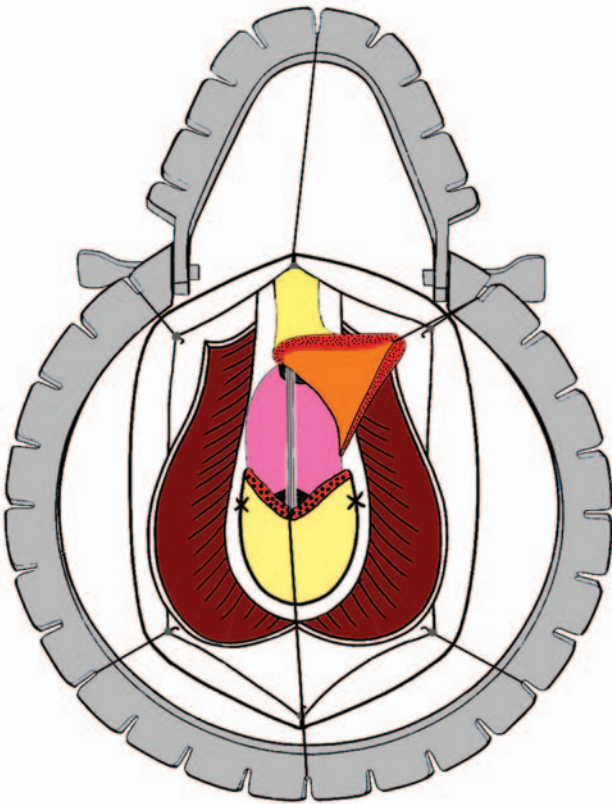


Figure 56.8 The distal urethra is pulled down and the proximal urethra is pulled up.

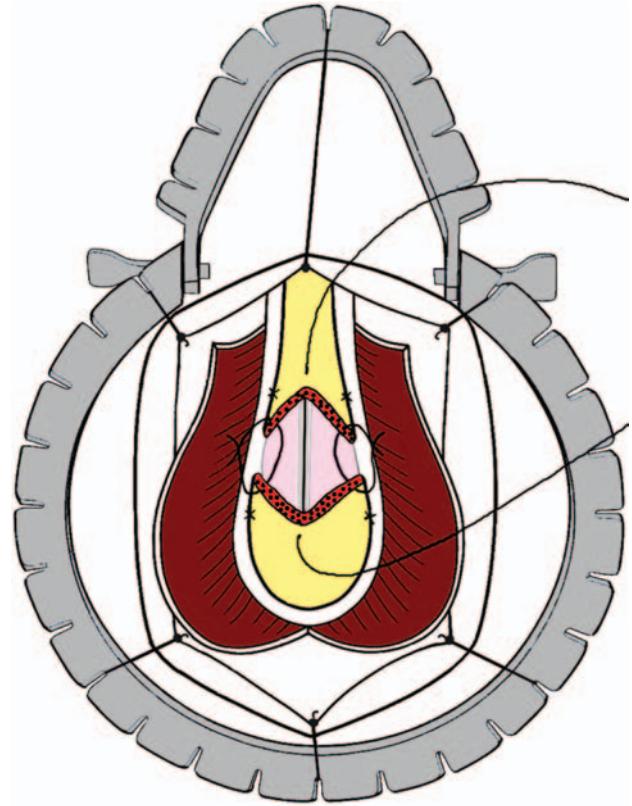


Figure 56.9 The urethra is rotated back to its original position. The distal and proximal urethral edges are sutured together along the midline as in an end-to-end anastomosis.

mucosa (16%). The skin group of patients did have a longer mean follow-up (71 months) compared with the buccal mucosa group (42 months). Yet, the penile skin group showed a higher number of failures involving the entire graft area (17% versus 6%), requiring surgical revision by using two-stage procedure.⁷

The controversy over the best means of reconstructing the penile urethra has been renewed and in recent years free grafts have been making a comeback, with fewer surgeons using genital flaps. The current literature, however, does not clearly support the use of one technique over the other. Rarely has a prospective study compared the graft with the flap, making it hard to declare a clear preference. That being said, however, the use of free grafts does not require extensive training in tissue-transfer procedures, as is required with the use of penile flaps. At present, we are not certain about the proper anatomic characteristics the penis should have to ensure that the grafts take. The penile spongiosum tissue and dartos fascia do not ensure good vascular and mechanical support to the graft in all patients. What type of vascular support can be used? In which patients would the use of a pedicled flap have better chances of success than a free graft?

Identification and use of criteria to more carefully select the appropriate procedure for the patient should help answer all of these questions and might clarify whether the use of a buccal mucosal graft is preferable to the use of a penile flap.

In 2004, Delvecchio et al suggested that the use of augmented roof-strip anastomotic urethroplasty incorporating the graft onlay into the receiving urethral plate is less successful, either because of the inherent deterioration of the transferred tissues exposed to urine or to the fact that the onlay is performed in a densely spongiofibrotic area, generally at the site the stricture disease originated, which is unsuitable for simple onlay grafting.⁸ These authors propose always excising this area, followed by direct reanastomosis of the floor-strip and onlay of the adjacent 'better' stricture, whatever its length.⁸ The authors show that this technique had only a 5.2% failure rate in 38 patients, compared with a 9% failure rate in 11 patients who underwent simple augmented graft urethroplasty without excision of the strictured tract. They concluded that excision of the worst stricture segment (up to 2 cm) avoids a long onlay in a poor urethral bed where failure often occurs at the location of even the

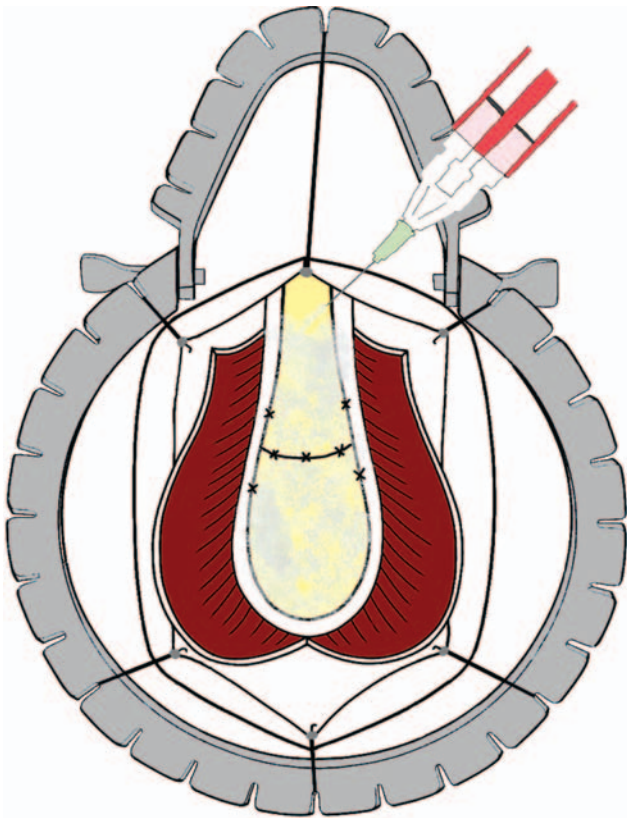


Figure 56.10 The grafted area is covered by the urethra and fibrin glue is injected over the urethra to prevent urinary leakage.

smallest stricture caliber.⁸ Abouassaly and Angermeier recommended complete excision of the stricture and the use of augmented roof-strip anastomotic repair in patients undergoing substitution urethroplasty for strictures that contain a particularly narrow or dense area of 1–2 cm in length.⁹ We retrospectively reviewed 107 patients who underwent surgical reconstruction for bulbar urethral strictures.⁷ Ninety-five patients underwent simple augmentation of the stricture with the onlay graft and 12 patients underwent excision of the stricture with augmented roof-strip anastomotic urethroplasty using dorsal onlay graft. Out of 107 patients, 85 (80%) treatments were considered successful and 22 (20%) failures. Seventy-five out of 95 augmented graft urethroplasties were successful (79%) and 20 (21%) were failures. Ten out of 12 augmented roof-strip anastomotic urethroplasties were successful (84%) and two (16%) were failures.⁷

Buccal mucosal graft onlay urethroplasty represents the most widespread method for repair of bulbar strictures and the location of the graft has become a contentious issue since we described our techniques of dorsal onlay graft urethroplasty.³ Success with buccal mucosa urethroplasty has generally been high with

dorsal or ventral onlay grafts.¹⁰ We retrospectively reviewed an outcome analysis of 50 patients who underwent three types of urethroplasty with the buccal mucosal graft placed on the ventral, dorsal, or lateral surface of the bulbar urethra.¹⁰ Out of 50 cases, 42 (84%) were successful and eight (16%) failed. The 17 ventral grafts were successful in 14 cases (83%) and failed in three (17%). The 27 dorsal grafts were successful in 23 cases (85%) and failed in four (15%). The six lateral grafts were successful in five cases (83%) and failed in one (17%). In our experience, the placement of the buccal mucosa grafts on the ventral, dorsal, or lateral surface of the bulbar urethra showed the same success rates (83–85%) and outcome was not affected by surgical technique.¹⁰ Moreover, stricture recurrence was uniformly distributed in all patients.

In conclusion, it is important to remember that all urethroplasty procedures have the potential to fail and that any substitution material has the potential to deteriorate with time. To date, the best technique is probably the one with which the reconstructive urologist is most comfortable. No single technique is appropriate for all situations and the successful surgeon will have a repertoire of methods from which to choose.

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57 Anterior urethral reconstruction: penile island flaps

Jeremy B Myers and Allen Morey

Although the ideal treatment for short anterior urethral strictures is segmental excision with spatulated reanastomosis, complex strictures measuring more than 2–3 cm are often not amenable to resection. For intermediate and long urethral strictures, urethral substitution via the use of penile island skin flaps has become a popular and effective therapeutic option. This chapter reviews the indications for penile skin flap urethroplasty and details the surgical considerations which promote optimal outcomes.

ANATOMIC CONSIDERATIONS

Both penile skin grafts and flaps have long been effectively utilized for urethral reconstruction. Flaps are differentiated from grafts in that they maintain their own blood supply. Grafts, on the other hand, are segments of skin or mucosa harvested and transferred to a recipient site without an intact blood supply. Grafts are thus dependent upon neovascularization at the recipient site.

Flaps are classified based upon several architectural characteristics. Flaps are first divided on the basis of their blood supply – whether there is one dominant artery or, alternatively, multiple smaller vessels supplying the flap. Those having a large dominant arterial vessel are referred to as axial flaps, while those with multiple smaller afferent vessels are called random flaps. Further classification of flaps is based upon whether the skin is left in continuity at the base of the flap (peninsular flap), or whether the skin is detached, with the underlying vascular pedicle comprising the only remaining connection to the proximal tissue (island flap).

Island skin flaps can be further distinguished based upon the nature of the underlying tissue mobilized with the overlying skin paddle. Either muscle or underlying fascia are often left adherent to the skin paddle to prevent devascularization of the flap and preserve the vascular continuity of the pedicle. A flap based upon muscle is referred to as a musculocutaneous flap, while a flap based upon fascia with an overlying skin paddle is referred to as a fasciocutaneous flap.

Penile fasciocutaneous skin flaps predominate in the realm of urethral reconstruction. Island flaps are

required in reconstruction of the urethra since complete inversion of the skin constitutes the inner surface of the neourethra. Peninsular flaps are commonly utilized in a rotational manner to cover the shaft of the penis after harvesting island flaps. Penile island flaps are random flaps, since skin along the penile shaft does not have dominant arteries that would form an axial vascular pedicle, but rather a plexus of interconnecting arteries from branches of the external pudendal artery.

The skin of the penile shaft and prepuce are supplied by the superficial and deep external pudendal arteries, which both arise from the femoral artery and course medially towards the penis.¹ The resultant dorsolateral and ventrolateral plexus of arteries form a robust vascular supply for the foreskin and prepuce (Figure 57.1). Venous drainage resides in a parallel network of dorsal and lateral veins running in the loose areolar tissue above Buck's fascia, within the smooth muscle sheath enveloping the penis known as the tunica dartos. The venous outflow coalesces at the base of the penis into the superficial dorsal vein, which then drains into the saphenous veins.

Penile island flaps are mobilized from the skin of the prepuce or the penile shaft. Two planes of dissection are developed. Buck's fascia is mobilized deep to all skin structures of the penis, immediately superficial to the tunica albuginea, and it is the major transporting structure which carries the skin island and vascular pedicle to the recipient site. The tunica dartos is mobilized superficially, immediately beneath the skin (Figure 57.2), this contains the vascular network required to sustain the skin island.³

INDICATIONS

Although penile skin flaps provide well vascularized, supple, hairless tissue which is ideal for urethral substitution, we have utilized flaps less often in the past decade because of the remarkable success of free grafts (especially buccal mucosa), which are technically much more efficient. Penile island skin flaps are best reserved for pendulous urethral reconstruction when distal complex strictures require extensive

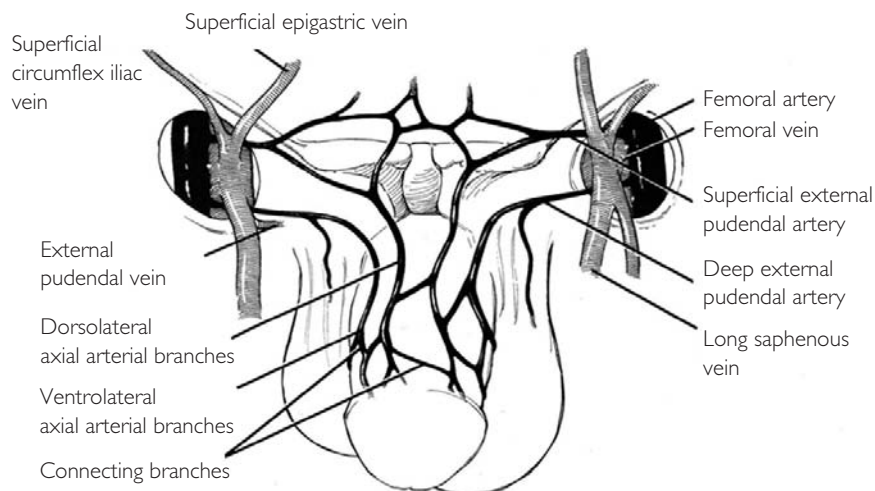


Figure 57.1 The blood supply of penile fasciocutaneous skin flaps is a rich plexus based on terminal branches of the superficial and deep external pudendal arteries. From reference 1, with permission.

reconstruction. The abundant corpus spongiosum found in the bulbar urethra constitutes an outstanding graft support bed, thus obviating the need for proximal flap pedicle transfer in all but the most severe cases.

Penile island flaps may easily be advanced distally to the urethral meatus, and have proven to be quite effective for fossa navicularis reconstruction. Longer strictures extending into the fossa navicularis (many of which are complicated by the presence of lichen sclerosis) do not fare as well as shorter, discrete fossa strictures after flap repairs.⁴ Penile skin being targeted for use as a flap should be of high quality – hairless and free of inflammatory changes. Trans-scrotal transfer of a penile skin island flap to the perineum is a challenging and time-consuming maneuver – this extensive genital dissection should be avoided in sexually active men since recent data indicate that flap procedures may be more bothersome to patients compared with more direct procedures such as anastomotic procedures and grafts.⁵

PENILE ISLAND FLAPS

Multiple techniques have been described for the use of penile island flaps for treatment of anterior urethra strictures. Of the various skin configurations that may be employed, the three most significant are the longitudinal (Orandi) flap, the hockey stick (Quartey) flap, and the circular (McAninch) penile fasciocutaneous flap.

The longitudinal (Orandi) flap

In 1968, Orandi first described a longitudinal penile skin flap for one-stage urethroplasty.⁶ The basis of the flap for a pendulous stricture is a pedicled strip of skin

overlying the ventral aspect of the corpus spongiosum. Skin is mobilized from preputial and penile shaft skin for the pendulous urethra and from the perineum for more proximal strictures.

To start the Orandi flap, a superficial incision is carried down the lateral ventrum of the penis along the border of the proposed flap. A deeper parallel median incision is carried beneath Buck's fascia, to ensure that tunica dartos fascia is dissected free to accompany the skin flap ensuring an adequate vascular pedicle for the flap. Once the initial dissection of the future skin flap has been performed, the strictured area is exposed and a urethrotomy is carried over the area of the stricture. A lateral urethrotomy may often be preferable since the corpus spongiosum is generally thinner there and the vascular pedicle supporting the flap may be placed under less tension. Orandi advocated oversewing of the urethrotomy's lateral edges for hemostatic control with a running locking stitch of absorbable suture, and we have also found this maneuver to be helpful in ensuring hemostasis.

Once the urethrotomy has been completed and stricture characteristics fully assessed, flap dimensions are determined. Epithelium on the raised flap is trimmed at the apices to define the desired shape. Once the flap has been defined, it is inverted and secured so the skin becomes the inner surface of the neourethra. The lateral edges of the urethrotomy are secured to the flap with a running 5-0 monofilament absorbable suture (Figure 57.2). A urethral catheter is left in place for a variable length of time determined by surgeon preference.

For longer strictures, the longitudinal incision may be extended down to the scrotum if the stricture requires a more proximal placement of the flap. Orandi also described the use of a perineal flap for

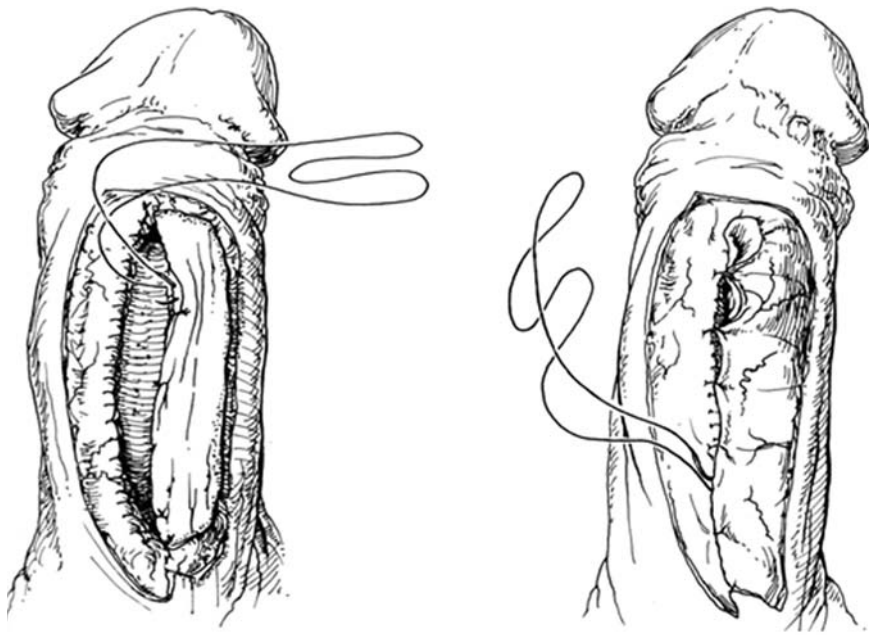


Figure 57.2 The longitudinal (Orandi) penile skin flap urethroplasty. From reference 2, with permission.

proximal strictures, but since these extended flap configurations usually involve hair-bearing skin, we rarely employ longitudinal flap techniques at our institution.

The 'hockey-stick' (Quartey) flap

Quartey expanded applications of the penile island skin flap in 1983 and detailed its superficial external pudendal blood supply using microinjection studies.⁷ Using various configurations, preputial skin was tailored according to stricture length and utilized as either a tube or an onlay. Quartey applied preputial flaps for strictures from the distal anterior urethra to the prostate with good success. Noting the average circumference of the adult penis to be 10 cm, Quartey found that a ventral flap with a dorsal or circumferential 'hockey stick' extension could provide up to 15 cm if necessary to bridge a long area of strictured urethra (Figure 57.3). The shape of the flap could be varied considerably from ellipsoid to linear to fit the needs of the repair.

The flap is begun with a deep circumferential incision just below the coronal edge to the depth of the tunica albuginea. A ventral extension is then carried over the urethra toward the penoscrotal junction. Stay sutures are placed at the apices of the ventral incision and the loose areolar subcutaneous tissue is dissected free from the tunica albuginea beginning ventrally and extending laterally to the dorsum of the penis. The flap is then outlined and incised just lateral and dorsal to the original incision in order to delineate the shape of the flap that is needed. The remaining sleeve of penile skin lateral and dorsal to the flap is dissected free from

the vascular pedicle supplying the flap. A relaxing incision may be made dorsolaterally in the vascular pedicle to allow maximum mobility for proximal placement.

The McAninch (circular) flap

The distal circumferential flap developed by McAninch in 1993 is the most versatile of all, and is utilized almost exclusively at our institution when flap urethroplasty is warranted.⁸ Its advantages include the fact that it virtually always provides abundant hairless skin, even in previously circumcised men. A full circular flap usually provides 12–15 cm of skin in adults. For synchronous urethral strictures, the flap may be divided into two pieces and/or passed under a scrotal tunnel to reach proximal strictures.

After the circular flap is outlined with a marking pen on the skin of the distal penile shaft, a deep distal degloving incision is undertaken beneath Buck's fascia circumferentially around the penis. This deep dissection plane is extended proximally until the penis is completely degloved. This provides complete urethral exposure, and the urethra is then bivalved along the length of the stricture.

The proximal edge of the flap is then defined by incising through the dermis alone, creating a 1.5–2.0 cm strip of preputial skin for the neourethra. Alternatively, the proximal flap margin may be lightly scored with a fresh scalpel at the outset of the case. The vascular pedicle is carefully dissected free from the overlying skin of the penile shaft. In this superficial dissection plane, the

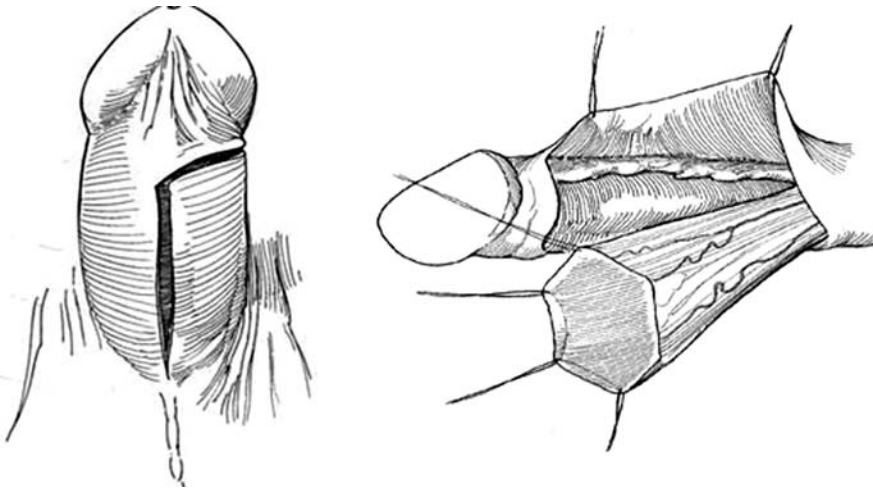


Figure 57.3 The 'hockey stick' (Quartey) penile skin flap urethroplasty. From reference 1, with permission.

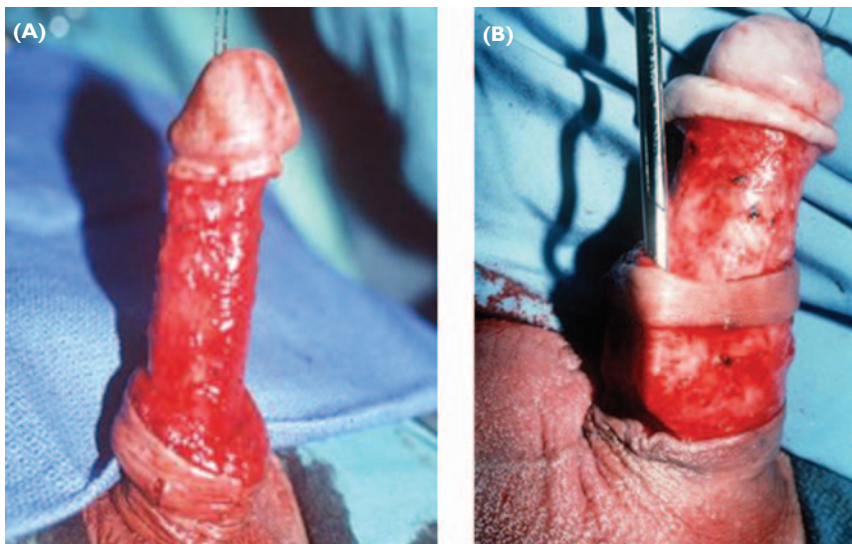


Figure 57.4 (A) The circular (McAninch) penile skin flap urethroplasty promotes complete urethral exposure during the initial degloving. (B) The circular (McAninch) penile skin flap is elevated on the superficial lamella of Buck's fascia and carries the thick tunica dartos, a robust smooth muscle sleeve which envelopes the penis.

subdermal plexus of the surrounding penile skin sleeve must remain undisturbed to prevent ischemic damage. The thick tunica dartos flap, transported upon the underlying Buck's fascia, is extremely robust and resilient in most adult men, thus providing excellent sustenance for the skin island being transferred (Figure 57.4).

Once the flap is completely mobilized it is divided, along with its vascular pedicle, down the ventrum of the penis. The skin flap is then rotated in either direction according to which has less tension, and it is then sewn as an onlay along the length of the urethra using 5-0 PDS suture (Figure 57.5). Redundant epithelium is carefully excised, preserving the entire supporting vascular pedicle, which is then interposed over the urethral suture lines to prevent fistula formation. Although the flap may be passed under a scrotal tunnel to reach the proximal urethra, this practice is discouraged in most cases because it is time consuming and may result in a sensation of penile tethering.

The Q-flap is a modification of the circumferential flap extended ventrally in order to gain additional length for use in panurethral strictures.⁹ This technique, although very demanding, may obviate the need for combination of graft and flaps in extensive or panurethral stricture cases. The flap is named for its appearance when marked upon the shaft and preputial skin; the circumferential nature of the flap with the ventral extension makes a 'Q' shape (Figure 57.6). The average skin flap that can be mobilized with this technique averages 17 cm and ranges from 15 to 24 cm.

OUTCOMES

In general, long-term outcome data for island flap urethroplasty have not been well reported. Orandi and Quartey in their original papers reported their outcomes in only small numbers of patients, numbering

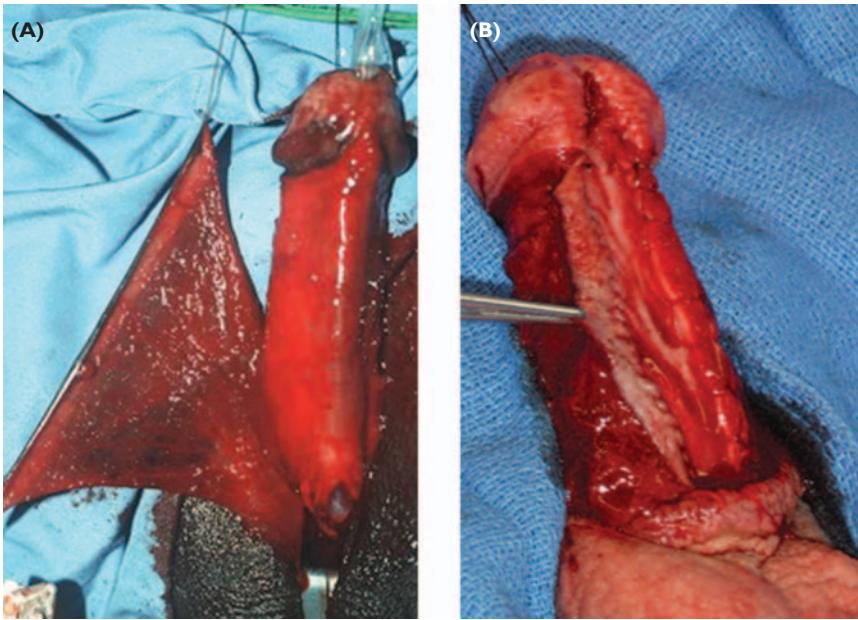


Figure 57.5 (A) The circular (McAninch) penile skin flap is divided ventrally and transferred to the side of least resistance. Up to 15 cm of hairless skin are provided using this technique. (B) The flap is then sewn to the bivalved urethral plate with running 5-0 PDS suture.

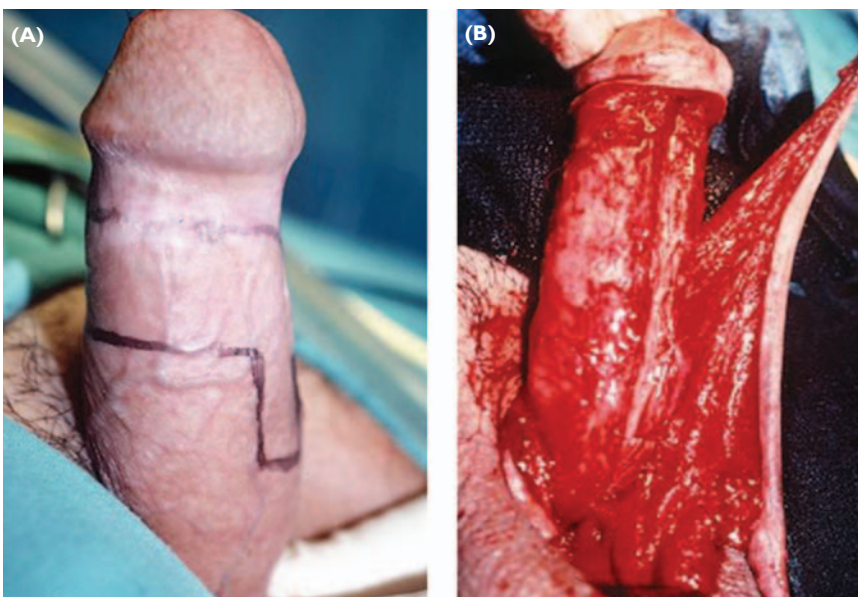


Figure 57.6 (A) The Q-flap is a circular penile fasciocutaneous flap with a ventral midline extension. (B) The Q-flap configuration can provide up to 24 cm of hairless skin for urethral augmentation.

21 and ten, respectively. Orandi did report in his 4-year outcomes that he had only one stricture recurrence and two other patients requiring transurethral resection of intraluminal hair for calcifications.¹⁰ In Quartey's series, of the seven men with anterior urethral strictures, only one recurred, which he attributed to inadequate excision of the original stricture. The Q-flap was utilized in 15 men for panurethral strictures and was found to have an excellent short-term result in ten of 13 men, followed for a mean of 42 months; two men were lost to follow-up.

The exception to this paucity of long-term outcome data is provided by Mundy et al in several contemporary papers. His first paper reported on 73 patients, treated with scrotal, preputial, and penile skin flaps.¹¹ Mundy found that tube flaps had higher re-stricture rates at 5 and 10 years, compared with patch flaps (36% for tube flaps and 19% for a patch flaps at 5 years, and 56% and 40% at 10 years, respectively). The use of scrotal skin also had an even higher re-stricture rate when used as either a tube or patch flap (89% for a tube and 62% for a

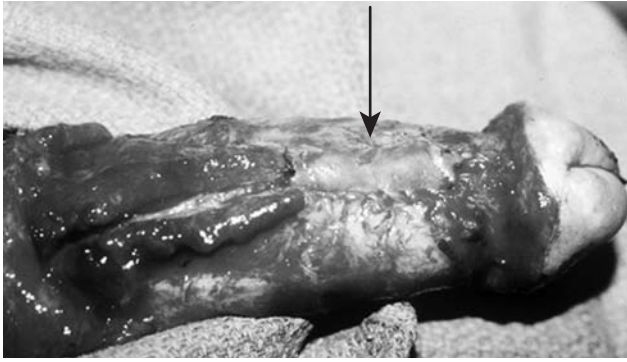


Figure 57.7 Urethral plate 'salvage' is accomplished via a short dorsal buccal mucosa graft in an area of focally severe stenosis, in conjunction with a penile skin flap only. Arrow indicates buccal mucosa graft used in conjunction with penile island skin flap.

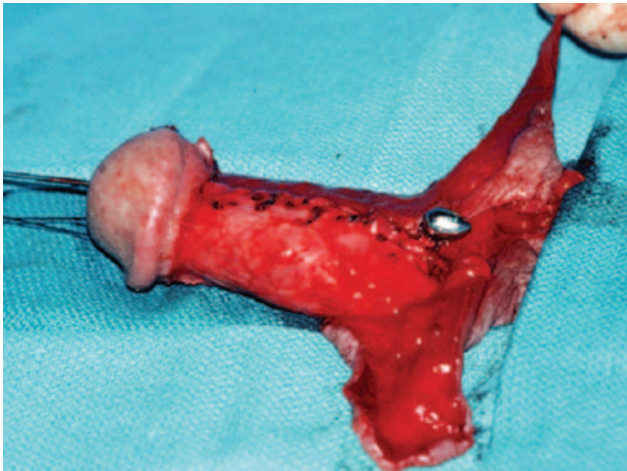


Figure 57.8 For extensive or synchronous repairs, a 'retrograde' surgical approach is performed in which the entire distal repair is completed in the supine position prior to leg elevation for bulbar urethral exposure.

patch flap at 10 years). Best results were achieved with penile or preputial skin for onlay patch urethroplasty, which showed a 31% re-stricture rate at 10 years and 58% at 15 years.¹²

Mundy's findings underscore the natural attrition rate in long-term patency observed with flap procedures (overall 5% restenosis rate per year). This trend appears not to be true for patients who undergoing anastomotic procedures, where 5-year success rates are essentially unchanged at 15 years.¹¹ Although it is unclear how long-term outcomes for free grafts like buccal mucosa will compare, there is no question that flap procedures are contraindicated for short bulbar strictures amenable to complete excision with primary anastomosis.

TECHNICAL CONSIDERATIONS

In preparing for skin flap urethroplasty, the penis must be placed on stretch via a thick 2-0 glans traction suture. When measuring the flap, calipers are helpful and it is critical to have the skin maximally stretched during marking. Otherwise, because the skin is highly elastic, redundant tissue may lead to sacculation within the repaired urethral segment.

We believe it is critical to assess the severity of the stricture at the time of reconstruction, and that flap dimensions must be adjusted accordingly. We believe the bivalved urethral plate should be no less than 1 cm in width – to confirm this, we routinely attempt to pass an 8 Fr feeding tube into the bladder as the first step of any penile flap urethroplasty. This simple maneuver verifies that the stricture is relatively uniform and mild in severity, thus allowing a 17 mm wide penile flap to be mobilized for a final urethral caliber of roughly 26 Fr.

When strictures are focally severe (when the 8 Fr tube does not pass into the bladder), a wider flap (20 mm) may be selected. We have found that segmental excision with a short dorsal buccal mucosa patch graft (Figure 57.7) for 'urethral plate salvage' promotes success from the flap onlay procedure.¹³ Alternatively, lateral advancement sutures along one edge of the urethral plate may be used to supplement the plate diameter by several millimeters when peri-urethral fibrosis is not extreme. Again, flap tubularization should be avoided whenever possible because outcomes of onlay repairs are superior.

Formal circumcision must be completed in uncircumcised men having extensive penile skin flap urethroplasty. Otherwise, the redundant distal prepuce may be at risk for ischemic damage which can create a troublesome postoperative course. Care must be taken during the reconfiguration of penile skin at the time of closure to avoid penile torsion.

Patient safety is of paramount importance during extensive urethroplasty procedures. Positioning in the high lithotomy position must be limited or completely avoided whenever possible since significant lower extremity complications may arise as a result of prolonged procedures in high lithotomy.¹⁴ The preferred surgical position for patients having pendulous urethroplasty is supine. In those having more proximal strictures, patients are placed in the lithotomy position only for perineal exposure. For complex or synchronous strictures, a 'retrograde' surgical approach is used in which the supine position is initially selected for mobilization of the penile flap and distal urethral exposure. Repairs extending into the distal bulb may be accessed adequately in the supine

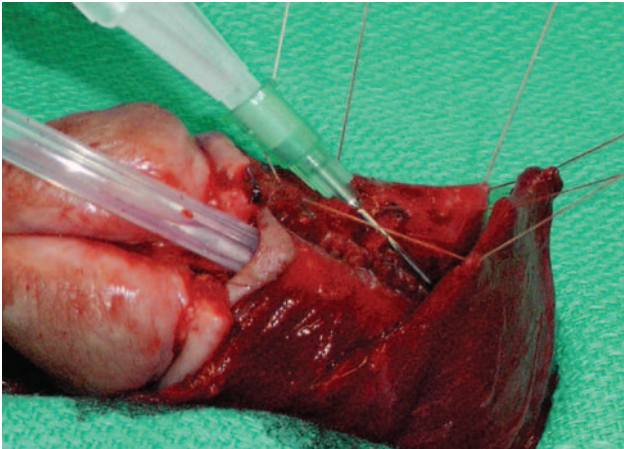


Figure 57.9 Fibrin sealant is applied along the completed suture line under a redundant layer of tunica dartos pedicle in order to promote healing and prevent urinary extravasation.

position. The entire distal repair is completed and the penile incision closed prior to repositioning the patient into the lithotomy position (Figure 57.8). Adjustable stirrups are helpful to safely and efficiently raise the legs as needed for bulbar exposure.

Although some surgeons advocate use of suprapubic cystostomy and drain placement at the surgical site, we have found neither of these maneuvers to be necessary. To prevent genital edema and hematoma postoperatively, we routinely use a self-adhesive bandage to provide gentle compression to the penis. The patient is instructed to unwrap and rewrap the bandage daily for the first 10 days postoperatively. We have also noted that fibrin sealant applied beneath the remaining sleeve of foreskin is helpful in avoiding penile shaft edema and hematoma.

Urethral catheter removal after penile flap urethroplasty is generally performed at 3 weeks. At that time, the bladder is filled with contrast and an oblique voiding cystourethrogram is performed to ensure complete integrity along the anastomosis. If extravasation is noted, a 16Fr coude catheter is immediately replaced and maintained for another week. We have noted that catheter duration may be significantly shortened by the use of fibrin sealant (Figure 57.9).¹⁵

CONCLUSIONS

Penile skin flaps remain an excellent method for reconstruction of long distal urethral strictures. Of the various flap configurations that have been described, the circular fasciocutaneous flap described by McAninch is the most versatile. For bulbar strictures, primary anastomotic repairs or graft procedures are preferred because of their simplicity and excellent outcomes. Penile island flaps should remain a viable alternative for difficult cases of anterior urethral strictures, like the panurethral strictures, or in cases when multiple techniques must be employed to create a patient urethra.

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58 Scrotal and perineal flaps for urethral reconstruction

Charles L Secrest

Flaps remain an important option for the reconstructive urologist when considering choices for posterior urethral reconstruction. Scrotal flaps are reliable, durable, and extremely flexible in their application when substitution urethroplasty becomes necessary.¹

There are many indications for flaps in urethral reconstruction. For the purpose of this discussion, the posterior urethra will include the bulbar and the true anatomic posterior urethra (prostatomembranous urethra). It is common to find that posterior urethral strictures involve the proximal bulb as well as a portion of the membranous urethra and therefore we look at these structures together. A stricture longer than 3 cm is the most common indication for flap urethral reconstruction. A large urethral defect, as seen in erosion injuries, is another common indication for a flap. Recipient wounds that are chronically inflamed are best reconstructed with flaps and this is true for urethral reconstruction as well. Buccal mucosa grafts have become very popular in recent years, but we have seen these procedures fail when applied to a severely scarred perineal wound for urethral reconstruction. Extremely long defects are also reparable with scrotal and perineal flaps. A scrotal flap onlay procedure can be used in combination with grafts for longer urethral defects by using the graft for the urethral plate and then the flap for the onlay as either a one- or two-stage procedure.

The proximity of the scrotal skin makes it ideal for reconstruction of the posterior urethra. The scrotal flap receives blood supply from two major sources, the internal and external pudendal arteries. The internal pudendal is a terminal branch of the hypogastric artery and the external pudendal originates from the femoral artery. The dual blood supply for this flap makes it a highly reliable source of skin for tissue transfer. The flap mesentery is the dartos fascia, which is thick and plentiful in the scrotum. The scrotal skin is extremely extensible. These flaps must be carefully tailored to meet the defect in order to avoid extra skin that may later lead to a diverticulum. The hair-bearing nature of this skin is usually not a problem in an appropriately tailored flap. Preoperative epilation of the skin can reduce the amount of scrotal hair-bearing skin used in urethral reconstruction. The nature of this flap

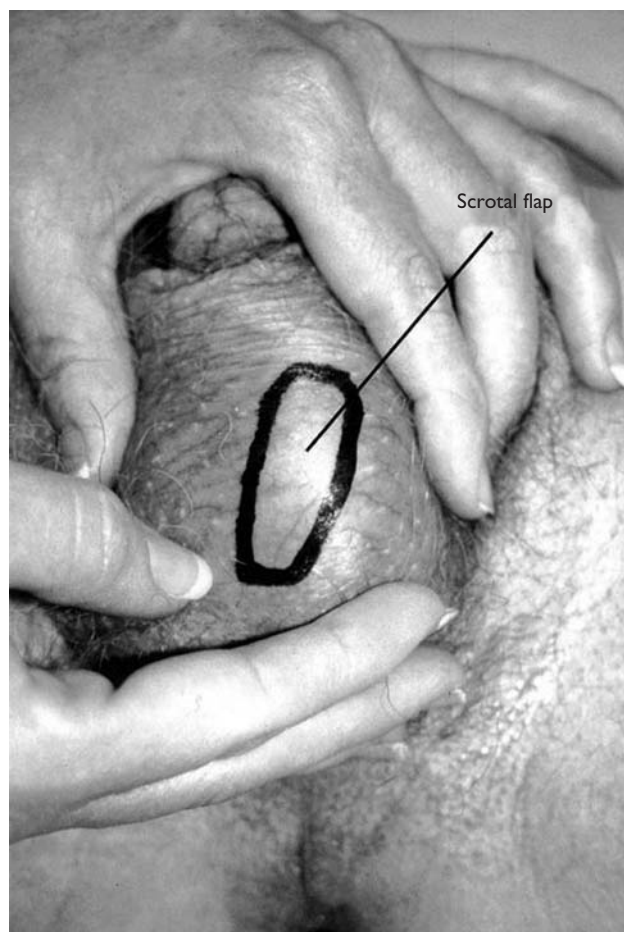


Figure 58.1 Midline hairless scrotal skin island marked prior to shaving.

allows for tubularization, if necessary, for extremely complicated cases. Generally we avoid tubularized flaps but there are certain cases that require full, circumferential reconstruction of the destroyed urethra.

The technique for flap development is fairly straightforward, but there are certain points that are critical for a successful outcome. A hairless scrotal island near the midline that runs in a longitudinal direction should be sought. Most men have a relatively hairless area, so it should be looked for in the office setting in any man referred for urethral reconstruction. In the operating room a permanent marking pen is used to outline the flap before shaving (Figure 58.1).

Even if an overly vigorous operating room nurse has shaved before marking, the surgeon can usually locate the desired region of the scrotum with relatively less hair. Again, incorporating hair-bearing skin into the urethral repair is not a problem if the flap is developed and trimmed properly. The patient is positioned in an anatomic, exaggerated lithotomy position using adjustable stirrups with circumferential padding and pneumatic compressive stockings. Exact positioning is critical in these cases that require more time than a standard anastomotic repair. However, flap development, transposition, and anastomosis should take no longer than 1 hour, thereby avoiding complications of prolonged dorsal lithotomy positioning.

Flap reconstruction is a delicate procedure that requires careful tissue handling and proper tissue transfer technique. Loupe magnification and fine surgical equipment including dissecting scissors, forceps, and skin hooks are requisite for this procedure. The initial scrotal and perineal incision is near midline, incorporating the medial portion of the flap in this deep dissection. Next, we expose the diseased urethra and assess the strictured urethral segment. After incising 1 cm into healthy urethra both proximally and distally, we make a template for the flap onlay. In the case of complete urethral obliteration, we create a flap that is of proper width to tubularize around a 24 or 26 Fr sound (Figure 58.2). The short, female urethral sounds work well for this step. The goal of this procedure is to create a urethra of 24 Fr caliber, and therefore the template is tailored accordingly. Once we are sure about the dimensions of the flap, the skin is incised sharply with a number 15 or smaller scalpel. This incision cuts through the skin and subdermal plexus, thus exposing the underlying dartos fascia. The dartos drives this flap and is a rich source of blood supply. Flap dissection is multidirectional and includes branches of both the internal and external pudendal arteries (Figure 58.3). It is a fairly short distance from the scrotal wall to the perineal urethra, and care should be taken not to over dissect this flap. The surgeon should test for tension on the pedicle periodically during the dissection. Once the flap will comfortably transfer and transpose to reach the defect, the anastomosis can be begun. It is wise to harvest more flap than is needed, and then to perform the final tailoring of the flap at the time of the anastomosis.

The flap onlay anastomosis is executed differently depending on the location of the bulbomembranous urethral stricture. The terms 'dorsal' and 'ventral' when referring to the perineal urethra are confusing and make it difficult to communicate with residents and

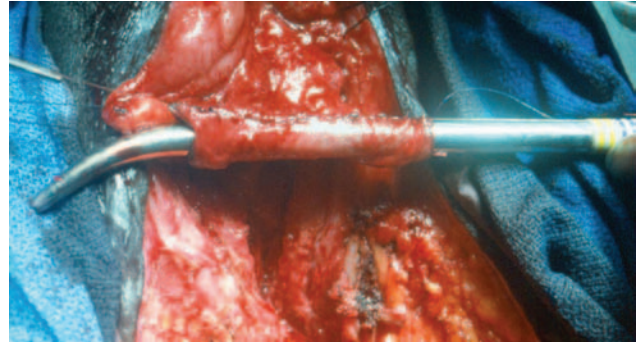


Figure 58.2 Scrotal island flap tubularized around a sound for full-thickness urethral replacement.

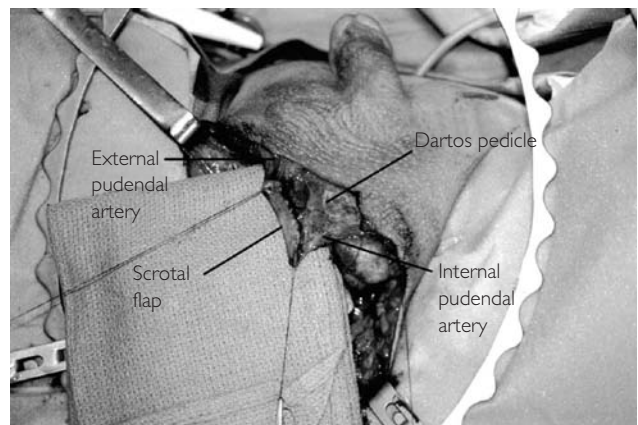


Figure 58.3 Hairless scrotal skin island mobilized on a dartos fascia pedicle supplied by branches of the internal and external pudendal arteries.

other physicians when describing urethral pathology. I prefer to use the terms 'superficial' and 'deep' when referring to various locations along the perineal urethra. Generally, for the more distal strictures, I prefer a superficial onlay anastomosis and for the proximal strictures a more lateral and deep location for the onlay. In the distal bulb, the spongiosum is fairly symmetric circumferentially and the superficial anastomosis obviates the need for extensive dissection and mobilization of the native urethra. In contrast, the proximal bulb is much thicker on the superficial surface and it is generally easier to mobilize the bulb on the side of the flap and roll it laterally to facilitate a deep anastomosis. The onlay is usually more lateral than deep, and this also makes it easier if the flap needs to extend into the membranous urethra. For extremely long strictures, a lateral anastomosis works best.

The flap must be sutured in carefully in order to avoid devastating complications during the postoperative course. We first secure the deep surface of the flap with tacking sutures of 4-0 monofilament, absorbable

sutures. The deep surface is the leading edge of the flap, which was the edge involved in the opening incision. This edge will be covered by the mesentery after the superficial flap edge is secured, thus making it deep to the dartos fascial pedicle. After the tacking sutures are placed, a running, watertight, simple suture line is performed to complete the flap to urethra interface. This is a full thickness, mucosa to epithelial anastomosis with care being taken to invert the edges toward the lumen of the urethra. The superficial, outer anastomosis is completed in a similar fashion. Final flap tailoring is completed as the tacking sutures are placed on this superficial flap edge. The exposed, superficial suture line is covered with the dartos fascia using widely spaced tacking sutures. A soft silicone Foley catheter is inserted at this point, and the most common size used is 16 Fr. The urinary stream is diverted with a suprapubic tube and the periurethral space is drained with a small, low pressure drain. Patients are kept on bedrest for 2 days and then allowed to ambulate slowly with no sitting allowed. If the wound has healed properly, we remove the stenting urethral catheter at 3 weeks and perform a voiding cystourethrogram. If the anastomosis

looks good, the suprapubic tube is plugged for a voiding trial over the next 2–3 days. After a successful voiding trial, the suprapubic tube is removed and the patients return for cystoscopy at 6 months. We then follow the patients annually with a flow rate and repeat cystoscopy as needed.

The scrotal flap is a reliable and durable procedure for reconstruction of the severely diseased urethra. Remember, the scrotum is your friend; the urethra, the enemy.

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59 Staged urethroplasty

D E Andrich and Anthony R Mundy

INTRODUCTION

The majority of patients with urethral strictures can be treated by a single-stage procedure. It may not be technically easy to do so, particularly with posterior urethroplasty, but the results are usually satisfactory. Unfortunately, there are groups of patients who do not do well with a one-stage approach. Typically, these are patients in whom a segment of urethra has to be excised leaving a circumferential defect which is too long to be bridged by mobilization and primary anastomosis or for whom this approach would be inappropriate. These are almost always anterior urethral strictures and most commonly penile (or pendulous) anterior urethral strictures.¹ This is unusual in the bulbar urethra because it is rarely necessary to excise a segment of the bulbar urethra except when a metallic urethral stent has been implanted and removing the stent means removing the urethra around it as well; and because there is considerable scope for bringing defects in length by mobilization of the bulbar urethra whereas there is little or no scope in the penile urethra.

On the other hand, it is quite common to need to excise a segment of the penile urethra because of either failed hypospadias surgery in the past leaving behind extensively scarred poor quality tissue, or lichen sclerosus affecting a significant length, if not all, of the penile/pendulous urethra.²

This is not to say that all complications of previous hypospadias surgery will require two-stage surgery. It may be possible to do a fairly straightforward repair of a simple stricture or fistula if the remainder of the previous repair is satisfactory with a normal caliber urethra and a good cosmetic result. In such cases there will be no need to excise the previous repair or make other corrections. Nonetheless, this will be required in many instances of salvage hypospadias surgery.

Likewise, not all penile strictures in patients with lichen sclerosus are due to lichen sclerosus but many, if not most, are and it is a common mistake to overlook this diagnosis. This is because lichen sclerosus is a disease of genital skin and using genital skin or even non-genital skin to repair it is almost always associated with recurrent stricturing at some stage.²

It is not simply because a segment of the urethra has to be excised that staged urethroplasty has a

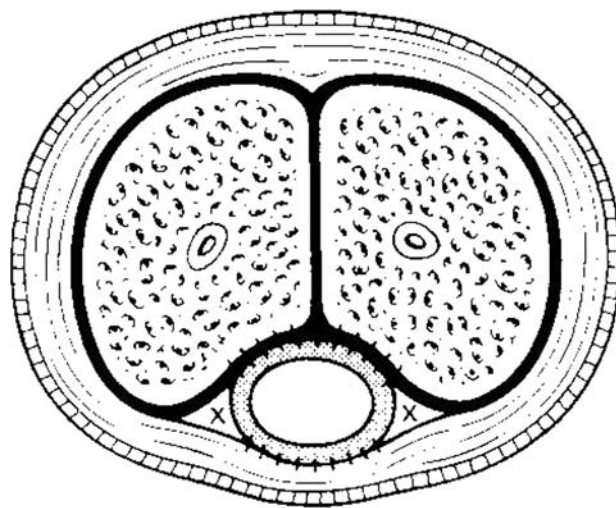


Figure 59.1 The variability of the vascular bed around a tube graft. There is good support dorsally on the corporal bodies and ventrally from the dartos fascia but a relative deficiency on either side (marked X). From reference 1, with permission. Reproduced with permission of Blackwell Publishing. All rights reserved.

significant role to play. The second and more important reason is that it is difficult to get a satisfactory result with a one-stage tubed reconstruction, however that tube is made. Tubularized grafts do poorly for reasons which are not entirely clear but may be due to the difficulty of providing good circumferential vascular support for a tube graft¹ (Figure 59.1). Somewhat more surprisingly, tubed flaps do not do well either. This may be because a tubularized flap remains untethered to surrounding structures (the way the normal corpus spongiosum is to the corpora cavernosa) and is therefore vulnerable, particularly as most tubularized flaps are of penile skin, which is inherently fragile, particularly to instrumentation.

Thus, staged urethroplasty is commonly required in the penile urethra for patients with lichen sclerosus-related strictures or for salvage after previous hypospadias surgery and, occasionally, in the bulbar urethra when a metallic urethral stent has to be removed with the surrounding urethra. The requirement for circumferential repair of the urethra coupled with the inherent tendency for one-staged tubularized repairs to do badly means that a two-stage reconstruction is commonly the best approach.

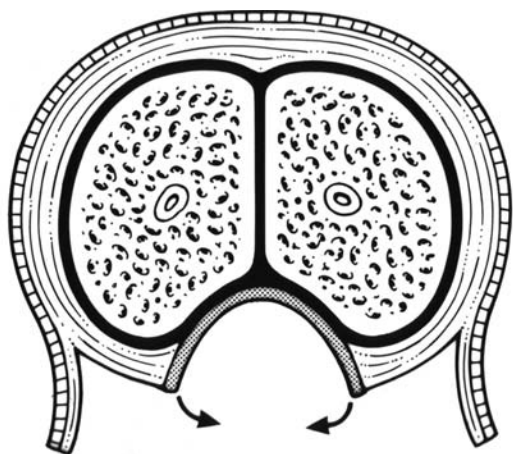


Figure 59.2 It is important to pick up a slip of dartos fascia on each side of the graft at the first stage to make it easier to undermine the two lateral margins at the second stage, as in Figure 59.3.

PRINCIPLES

The principle of a staged repair is therefore to excise the diseased segment and replace it with a flat free graft at the first stage, which is then rolled up to form a tube at a second stage. Currently, with buccal mucosal grafts in particular, it is easy to get a good take at the first stage as long as steps are taken to allow this to be rolled up easily into a tube so that at the second stage a satisfactory result may be more or less guaranteed. The key here is to fix the middle third of the graft (longitudinally) directly onto the tunica albuginea of the corpora cavernosa (between the two ends of the normal healthy urethra or between normal urethra and the tip of the penis), but on either side – the parts that will be rolled up inwards to form a tube at the second stage – to tack in some dartos or similar healthy supporting tissue between the graft and the tunica albuginea so that it can be undermined and rolled up comfortably at the second stage without having to carve the graft off the tunica albuginea, which would otherwise be necessary (Figures 59.2 and 59.3).

PROCEDURE

The typical example is a patient who has a lichen sclerosis-related stricture of the penile urethra. This may involve a variable length of the penile urethra from just a meatal stricture, or more commonly a meatal and fossa navicularis stricture, to a full length stricture of the penile urethra (Figure 59.4). Interestingly, the stricture rarely extends to the bulbar urethra and there is usually a very abrupt demarcation between the

diseased and healthy urethra. Sometimes, just the urothelium and the underlying spongy tissue are involved; sometimes the entire spongiosus is so fibrotic that it is readily palpable on clinical examination and on excising the urethra at operation it is so rigid that it is difficult to physically open it up to see the inside of the urethral lumen. Indeed, there are some patients, particularly elderly patients, in whom it is probably simplest and easiest just to do a perineal urethrostomy to allow them to void normally without the requirement for extensive staged surgery.³ Such surgery should only be considered in a young fit patient who has a reasonable chance of a successful outcome and who is likely to enjoy the benefits of it.

FIRST STAGE

Having excised the urethra, buccal mucosal graft is harvested from one or both cheeks. Some prefer to close the donor defect; we prefer to leave it open as we find patients recover more quickly, feel more comfortable, and have less swelling when the donor site is left open.⁴ The normal urethral caliber is about 26 or 28 Fr in the penile urethra and so a graft of at least 2.6 or 2.8 cm must be harvested, and probably a little larger as there is the likelihood that a buccal mucosa graft may shrink by 5–10% with prolonged exposure to the atmosphere.

In most patients with severe lichen sclerosis the glans cleft has been lost and this must be recreated by making a deep incision into the central midline of the glans spongiosum. This will also be commonly necessary in patients with hypospadias-related problems. In the glans the graft is then quilted to the spongy tissue and sutured to the skin margins. On the tunica albuginea of the corpora cavernosa the middle third of the length of the stricture should be quilted directly onto the tunica albuginea; on either side, a slip of dartos (Figure 59.2) muscle should be interposed between the graft and the tunica albuginea, and quilted stitches should go through the dartos layer into the tunica albuginea to hold the dartos layer in place. The margin is then sutured to the adjacent skin margin thereby leaving the central buccal mucosal graft strip ‘marsupialized’.

SECOND STAGE

When the graft has healed satisfactorily, usually a minimum of 3 months but rarely more than 6 months later, the patient can then be brought back to have the second stage in which the graft is rolled up to form a tube. The junction between the skin and the buccal



Figure 59.3 The importance during the second stage of having incorporated a slip of dartos under the lateral margins of the graft at the first stage as in Figure 59.2.



Figure 59.4 Typical radiologic features of a lichen sclerosus/balanitis xerotica obliterans stricture with extensive and severe involvement of the penile (pendulous) urethra with an abrupt transition to normal bulbar urethra.

mucosa is incised. Because of the dartos interposition under the lateral aspects, the buccal mucosal graft is undermined relatively easily on either side and rolled up to form a tube. This does not need to be a perfect tube. Creating a tube with an oval cross-section rather than a circular cross-section (Figure 59.5) reduces the degree of undermining necessary to create it and thereby reduces the incidence of subsequent ischemic complications. Suturing the subepithelial layer rather than the epithelium (Figure 59.6) reduces the risk of postoperative fistulation. This is then closed. A lateral strip of buccal mucosa is excised from the glans at the distal end of the graft where the glans spongiosus underlies it, so that a second layer of closure is possible of glans spongiosus distally, and of the dartos layer more proximally. This second layer of closure, especially of the dartos, is extremely important to reduce the risk of fistulation. The skin is then overclosed on

the glans and on the penile shaft skin to provide a third layer of closure.

After both stages the urethral catheter is left in place for about 10–14 days to allow spontaneous urethral voiding. After the second stage, it is important to keep the catheter and the penis up against the abdominal wall so that the catheter does not press on the suture line of the glans closure (when present) which would tend to ‘unzip’ the suture line and create a hypospadias.

PROBLEMS

It would be good if all two-stage reconstructions were indeed two-stage reconstructions but unfortunately, and inevitably, complications do happen from time to time.⁵ After the first stage, about one-third of patients require revision, most typically for stomal stenosis or because the deepened glans cleft has shallowed out and needs to be deepened again in order to get a satisfactory terminal meatus. For patients with less concern about the cosmetic appearance of the external meatus, this may not be necessary. Fortunately, regrafting is rarely necessary indicating that the technical success of such surgery is high. The problems of shallowing of the glans cleft and of stomal stenosis are more likely to be attributed to the nature of the underlying disease. Such problems are much more common in patients having surgery for lichen sclerosus than for hypospadias, and lichen sclerosus exhibits the Köbner phenomenon of a tendency to recur in traumatized tissue. Given that buccal mucosa is not prone to lichen sclerosus, it is the glans, the marsupialized glans margins, and the urethrostomy that are therefore prone to problems.

As with the first stage, there are occasional revisions necessary after the second stage as well. About 25% of patients require early intervention to drain a hematoma or to re-suture a wound, occasionally to correct a postoperative fistula. Our policy has always been to

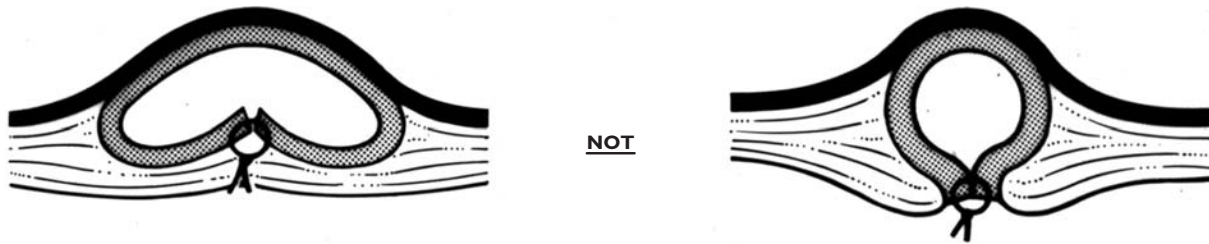


Figure 59.5 It is not essential to make a perfectly tubular urethra. An ovoid urethra is perfectly satisfactory and requires less undermining of the lateral margins of the graft and therefore less risk of ischemia of those margins as a consequence. The caliber rather than the shape of the urethra is the important factor.

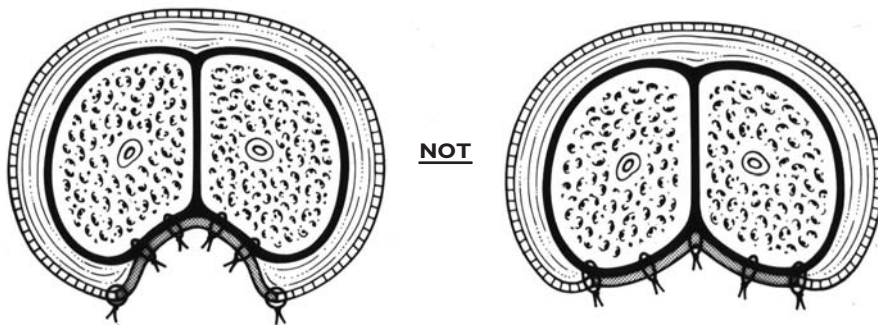


Figure 59.6 Rolling in the lateral margins by using a subepithelial suture reduces the risk of postoperative fistulation.

intervene early to drain a hematoma or to re-suture a wound in the belief that a hematoma and secondary infection are likely to lead to re-strictureing or to fistulation and so early intervention to drain a hematoma is sensible. It is reassuring that the re-stricture rates for staged urethroplasty are no higher than after one-stage urethroplasty of the bulbar or penile urethra possibly for this reason.

Why patients are prone to postoperative hematoma is not clear. It might be a technical problem but it might be the problem of postoperative erections and the tendency to bleed associated with that. Unfortunately, it is almost impossible to stop men having erections in the early postoperative period so one simply has to be alert to the possibility of hematoma, the need for careful preoperative hemastasis, and the need to evacuate it when it does occur.

SUMMARY

In summary, two-stage reconstruction of complicated urethral strictures seems to reduce the re-stricture rate significantly as compared with one-stage tubed repairs, but it does so at the expense of a significant revision rate. This means that in practise about 50% of patients will have a three-stage rather than a two-stage procedure to reduce the re-stricture rate from about 18%, as

it might have been had they only had a one-stage repair, to 4%. For this reason – the requirement for three stages in 50% of patients – and because the majority of these occur in patients with lichen sclerosus, it is sensible to consider a one-stage perineal urethrostomy in the more elderly patient, or in the less cosmetically sophisticated patient where a one-stage procedure (in this case perineal urethrostomy) can restore the patient to normal voiding, although without taking account of the other problems associated with a urethral stricture.

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60 Combined use of fasciocutaneous, muscular, and myocutaneous flaps, and graft onlays in urethral reconstruction

Leonard N Zinman

The ability to achieve a long-term, stable, stricture-free, and hairless urethral lumen in patients with complex anterior strictures and posterior urethral separation defects in the presence of adverse wound settings is one of the ongoing challenges of reconstructive urologic surgery. Genital fasciocutaneous flaps, buccal mucosa grafts, or some combination of the two in a one-stage or multistage fashion is currently the standard of surgical care for strictures not suitable for anastomotic repair. There is, however, a unique subset of patients with complex urethral pathology and refractory fistulas who have undergone multiple failed prior procedures, prior radiation therapy, skin loss from trauma or decubiti, and impaired wound healing that will require transfer of an extragenital flap for successful resolution. With the advent of the axial flap and the understanding of the vascular anatomy of muscular, myocutaneous, and fasciocutaneous flaps, and their ability to cover and enhance the healing ability of a compromised wound, an alternative armamentarium of reliable flaps is currently available as critical adjuncts for this challenging pathology. The flaps can be transferred as islands, hinges (peninsular), and free forms with minimal donor site morbidity. A group of extragenital flaps utilized in trunk and lower extremity defects are the most suitable for salvage of high-risk urethral disorders.^{1,2}

MUSCLE-ASSISTED FULL-THICKNESS SKIN AND BUCCAL GRAFT URETHROPLASTY

The expectations of full-thickness skin grafts have not been consistently achieved but their advantages for the repair of anterior urethral stricture are hard to overlook.³ The advantages of buccal mucosa or skin grafts include ease of application, wide versatility, multiple hairless donor sources and the ability to construct a conduit that most closely resembles a normal functioning urethra with rare sacculation. The addition of the buccal mucosa graft, a major change in the reconstructive paradigm, has proven to be an invaluable addition

as a one- or two-stage procedure for the complex posthypospadiac, the patient with balanitis xerotica obliterans (BXO), the radiated, and the reoperated fistula, with less contracture and more reliable revascularization as a result of its unique anatomy which includes a thin and highly vascular lamina propria.^{4,5} It has extended the ability of free graft material to resolve a longer stricture or a large, fixed refractory fistula with an early impressive record of success, but still remains at risk of partial or complete graft loss in the presence of an adverse fibrotic hypovascular periurethral tissue bed. This clinical setting requires a change in graft recipient site vascularity to ensure reliable inosculation, a concern that can be managed by transferring a number of trunk or thigh muscle flaps adjacent to the graft subdermal or lamina propria surface.

Skeletal muscles have an established role in resolving complex wounds, osteomyelitis, prosthetic graft sepsis, and repair of tissue defects and fistulas that develop under unfavorable conditions.⁶ They can provide coverage, obliterate dead space, separate suture lines, and improve vascularity and enhance white cell function in chronically fibrotic and impaired wounds with minimal morbidity.⁷ The use of a skeletal muscle surface intimately secured to the dermal side of a skin graft or buccal mucosa undersurface with proper immobilization will promote more predictable and rapid inosculation and prevent seroma formation and contracture.

The optimal muscle flaps available for urethral and perineal reconstruction include gracilis muscle utilizing four different techniques, the rectus abdominis, gluteus maximus, rectus femoris, semitendinosus, and the free latissimus dorsi. The most versatile and readily retrieved muscle is the gracilis, which can be transferred simply as a support for a skin or buccal graft in either a dorsal or ventral position. Three additional variations of transfer of the gracilis muscle include a short version of the gracilis which offers more muscle volume for preventing dead space, the myocutaneous technique which is the incorporation of a potential skin paddle for defect coverage in an island or peninsular form, or the prefabrication of a skin graft and

subsequent transfer of the muscle which carries with it an established neovascularized skin graft island.

GRACILIS FLAP: ANATOMY AND RETRIEVAL FOR URETHRAL STRICTURE DISEASE

The gracilis muscle remains the reconstructive workhorse of the perineum, groin, genitalia, and anal musculature. As a free flap, it has widespread application in coverage of the head, neck, and extremities, as well as a functional muscle in facial reanimation, and it can play a major role in the salvage of high-risk urethral pathology burdened by wound healing adversities. Its anatomy has been reliably defined by numerous studies that have identified its blood supply, innervation, and functional characteristics.^{8,9} It is approximately 24–30 cm in length with a 6 cm width proximally and a 4 cm width distally, and originates from the inferior ramus of the pubis and inserts into the medial tibial condyle. The width of the muscle can be extended by splitting the investing epimysium, which will increase the width an additional 30–50%. It is an expendable muscle since the adductor longus and magnus totally replace the function of adduction of the thigh. Reconstructive surgeons favor it for its reliable vascular supply, the ease of retrieval, its expendability, and its proximity to the perineum. It is located in the medial compartment of the thigh as its most superficial structure where it is readily accessed for complex urethral disease. The vascular anatomy of the flap and skin paddle cutaneous perforators completely governs the transferred location and extent of recipient site coverage. The main arterial supply to the muscle is the medial circumflex femoral, which is a proximal branch of the profunda femoris and enters the muscle 10 ± 2 cm from the pubis on its deep inferolateral surface. It is accompanied by two veins and the anterior branch of the obturator nerve. There are, on occasion, two arteries and an origin from the adductor pedicle. The medial circumflex femoral pedicle measures 7–10 cm in length coming out between the adductor brevis and the adductor longus with a number of small branches to both muscles. It enters the muscle and branches into four or five branches, which then pass proximally, and distally consistently supplying the entire muscle allowing ligation and division of the two distal insignificant branches (Figure 60.1). A second, less robust, pedicle supplying the proximal half of the muscle comes from the obturator branch of the internal iliac artery, which will permit ligation of the dominant medial circumflex femoral and allow a more proximal rotation point and transfer of a larger muscle mass.¹⁰

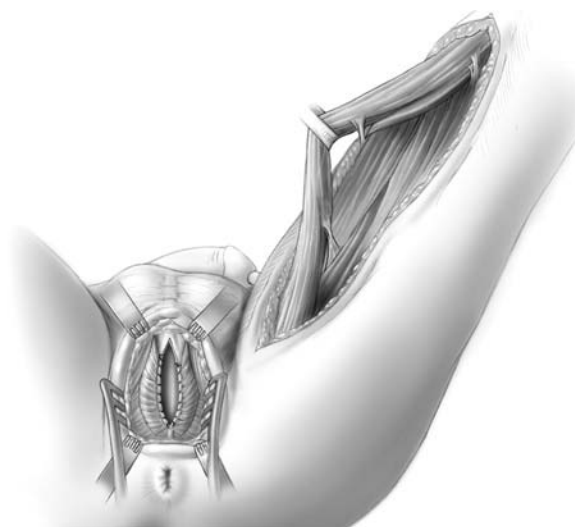


Figure 60.1 The gracilis muscle with proximal dominant pedicle and two distant minor pedicles.

Elevation of the flap is accompanied by first drawing a line between the pubic tubercle and the medial condyle of the femur with the leg in the straight, slightly abducted position. A parallel incision is made 2 cm posterior to this line starting distally where the musculotendinous insertion is identified posterior to the saphenous vein and distal sartorius muscle. The gracilis tendon is palpable medial to the semitendinosus muscle on the medial edge of the popliteal space. A drain is placed around the tendon and the muscle is exposed proximally by inserting an index finger between the anterior muscle surface and the skin in the subfascial tunnel, extending the incision in a proximal direction to the groin crease. The maneuver facilitates rapid mobilization of the entire structure with good exposure of the pedicles. The exposures can be achieved in a thin patient by a series of three short incisions while retaining the proximal thigh and inguinal crease tunnel, thus utilizing a less invasive technique. The two most distal minor pedicles are ligated and divided, and the proximal dominant pedicle is preserved (but not skeletonized) to avoid vascular spasm and injury.

TECHNIQUE OF BUCCAL MUCOSA GRAFT ONLAY WITH GRACILIS SUPPORT

The proper sequence for this procedure is to prepare the urethra, then to mobilize the muscle, and finally to harvest the buccal graft after a suprapubic diverting cystotomy is established. The urethra is prepared ventrally with exposure through a midline perineal

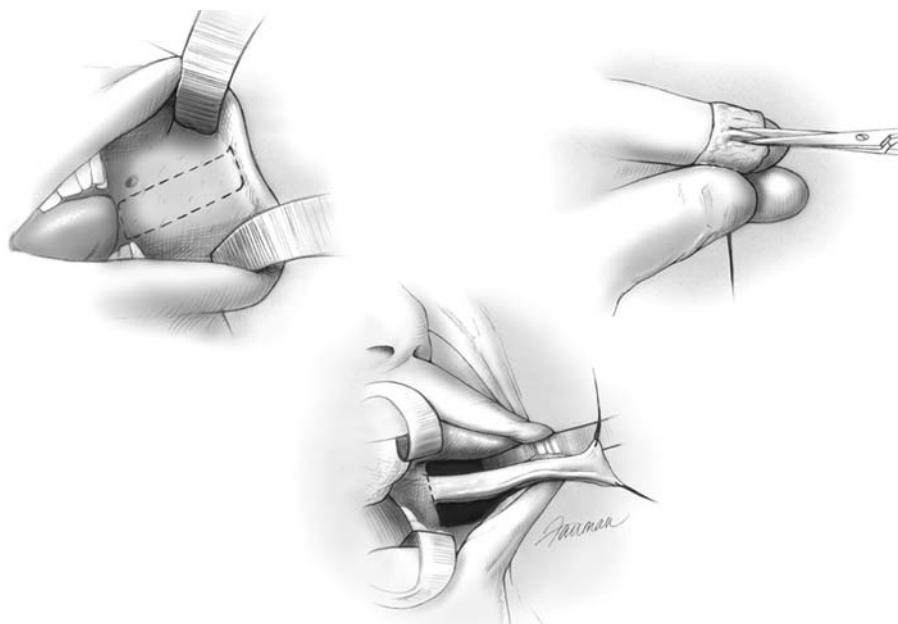


Figure 60.2 Buccal mucosa graft can be retrieved from one or both cheeks. The opening to Stenson's duct is identified opposite the second molar. The lower lip should be avoided as a donor site. A 2.5 cm × 6–10 cm can potentially be harvested if the dissection is extended from tonsillar pillar to the lip edge. The graft is carefully cleaned and thinned by placing it on the forefinger under tension, and removing the fibrofatty surface until a white, shiny surface is obtained.

incision extending into the mid-scrotal raphe. The bulbocavernosus muscle is divided and carefully preserved, since it will be sutured to the edges of the applied gracilis. A urethrotomy is started distally and extended for 2–3 cm beyond both ends of the stricture. Hemostasis from spongiosal edge is achieved with locked running 5-0 chromic catgut sutures along the urethrotomy margin. Extensive, severely fibrotic or radiated corpus spongiosum should not be excised unless there are obliterated segments since the traditional expected elasticity is often absent in the presence of severe spongiosis so that ventral penile tethering may develop.

A buccal graft is preferably obtained from the inner cheek, where a 6–10 cm × 2–2.5 cm strip of mucosa can be harvested with minimal morbidity, depending on the contour and shape of the mouth. The length and width of the urethral defect should be measured over a 28 Fr template. The head and neck are hyperextended and the face and jaw are draped without antiseptic preparation. A side bite (Jensen) retractor or a small Weitlaner is placed in the lateral edge of the mouth opposite the site of retrieval, after a transoral endotracheal tube has been inserted. Two short, right-angle retractors are placed under the lips and a rectangle of mucosa measuring 2–2.5 cm × 6–10 cm just inferior to Stensen's duct is retrieved after submucosal infiltration with epinephrine 1:100 000 dilution (Figure 60.2). The graft is transected at the level of the anterior tonsillar pillar and placed in a saline soaked sponge while the donor site is closed. If a lower lip retrieval donor site is used it should be left open. A lower lip donor site is best avoided if possible since the complication of

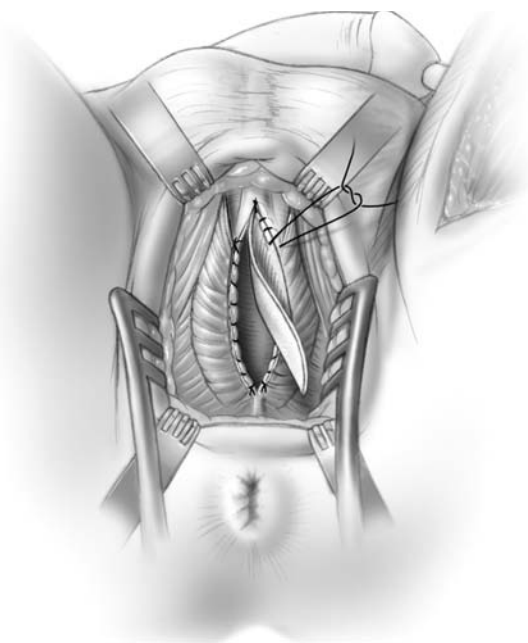


Figure 60.3 A full-thickness skin or buccal mucosa graft is sutured into the urethrotomy over a #24 catheter stent with interrupted 5-0 Monocryl.

contraction of the lip and perioral numbness is not an uncommon complication of this donor site. The graft is meticulously defatted on the surgeon's forefinger until a thin, white surface is obtained. The measured graft is fixed into the urethroostomy with three stabilizing apical sutures of 5-0 Monocryl at each end followed by a running suture along the margins. Excess graft length is managed by extending the urethrotomy distally until there is a proper fit (Figure 60.3).

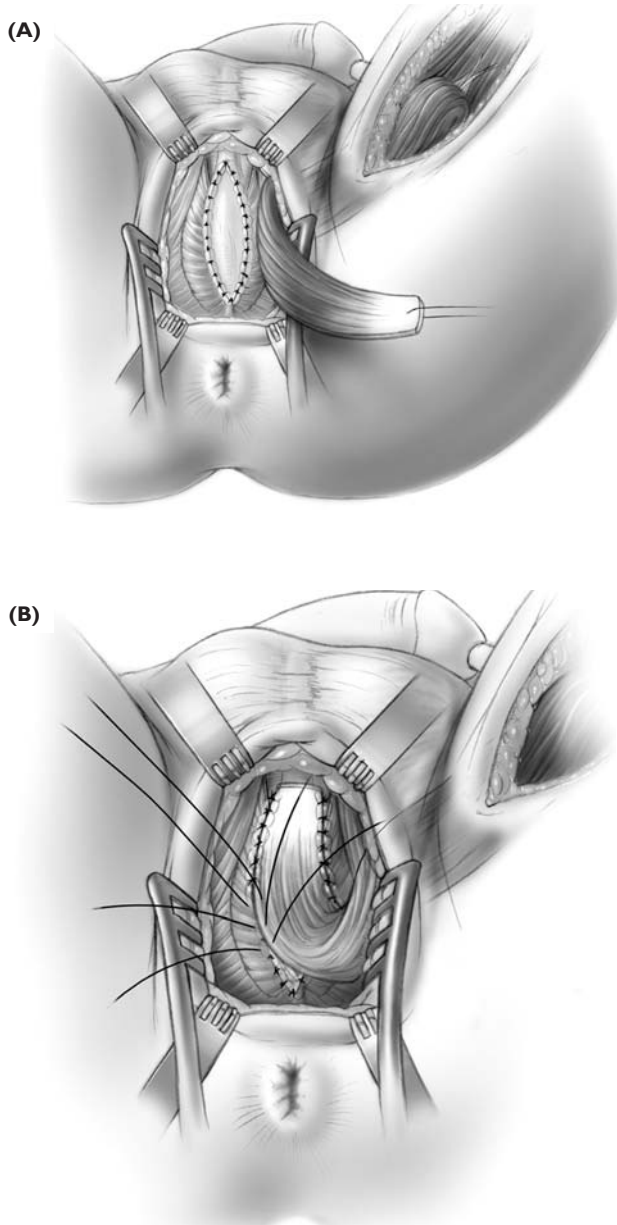


Figure 60.4 The gracilis muscle is detached distally, and the muscle flap is transferred through a capacious subcutaneous medial thigh tunnel. It is applied securely to the dermal surface or lamina propria undersurface of the buccal graft by suturing its margin to the periurethral fascia.

The gracilis muscle is transferred into the perineum through a capacious tunnel to prevent compression ischemia. The muscle surface is placed over the graft and anchored firmly to periurethral tissues. The bulbocavernosus muscle is sutured to the lateral surface of the gracilis (Figure 60.4). If there is residual dead space or a larger perineal defect than expected is created by the repair, then both gracilis muscles are transferred for muscle bulk.

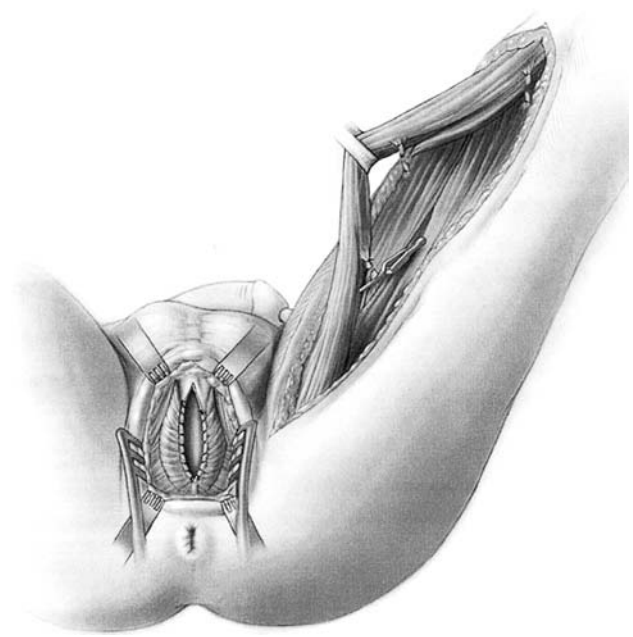


Figure 60.5 The use of a 'short' gracilis muscle with the proximal dominant medial circumflex femoral vascular pedicle divided permits a larger mass of muscle for transfer when more extensive coverage is needed.

SHORT GRACILIS FLAP

The long traditional gracilis muscle may not always be suitable for some patients when the mobility is limited by the location of the vascular pedicle and the defect is not adequately covered. The short version of the muscle offers a very useful alternative with more mobility, a larger bulk of muscle mass to fill a large defect, and prevents a bulky appearing deformed upper medial thigh, which can easily abduct without tension.¹¹ To achieve this kind of mobility for more extended coverage, the main proximal vascular pedicle is first occluded with a vascular clamp and an intact axial circulation confirmed by a Doppler probe (Figure 60.5). It is then divided and the muscle dissected proximally to its origin on the inferior pubic ramus dividing the fascia and rotating it through a previously created wide tunnel. This fully mobilized muscle with a cutaneous component will also consistently survive on circulation from the terminal branches of the obturator artery, which enters the muscle at its origin.^{10,11}

DORSAL PLACEMENT OF BUCCAL GRAFT AND GRACILIS MUSCLE

In the paraplegic patient with a bulb stricture, a traumatic fistula secondary to erosion of the dorsal surface

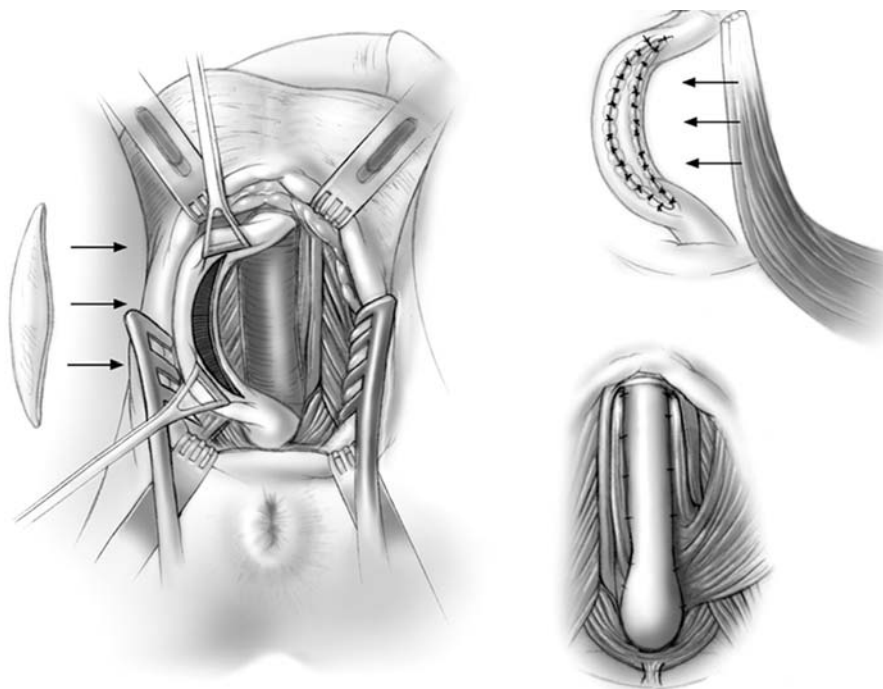


Figure 60.6 Dorsal wall injuries can be repaired by making a dorsal urethrotomy and fixing a buccal onlay at both apices followed by a muscle flap interrupted between the graft and the ventral corpora.

of the urethra from pressure against the pubic arch or a central decubitis, a dorsal approach to the urethra with a muscular buttress on either surface may be the optimal reconstructive procedure. The bulbar urethra is widely mobilized and a dorsal urethrotomy is created by rotating the spongiosa to gain access for a 12 o'clock urethrotomy in a relatively avascular site. The graft onlay is completed with interrupted 5-0 Monocryl sutures and the muscle is transferred to the perineum in the long form and placed between the dorsal graft bearing surface and corpora cavernosa. The muscle edges are sutured to the spongiosa and a perineal artery or posterior thigh fasciocutaneous flap can be transferred for a perineal cover (Figure 60.6).

PREFABRICATION COMBINED BUCCAL MUCOSA AND GRACILIS FLAP RECONSTRUCTION

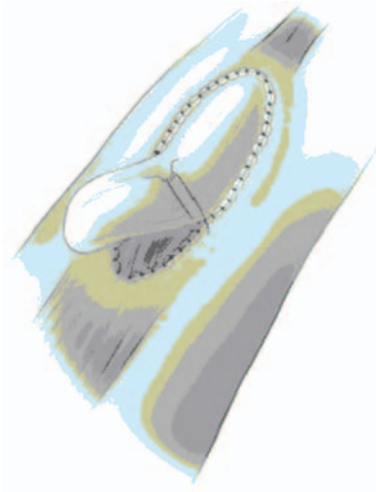
The concept of establishing a vascularized skin graft by initially securing its vascular support before tissue transfer offers an entirely new dimension in the management of strictures with periurethral beds compromised by extensive avascular fibrosis, fistulas and radiation by prefabricating a skin or buccal graft at a distant site in the medial thigh to establish a reliable circulation and transferring it to the urethra as an onlay.¹² The uncertainty of precarious, unpredictable inosculation can thus be avoided. This permits a skin component without

excessive bulk in a more distal site on the muscle flap. The gracilis muscle is first exteriorized through a 10–12 cm incision over its distal third, suturing it to the dermis at skin's edge (Figure 60.7A). A graft is sutured to the edges of the exposed anterior muscle surface, pie crusted, and quilted to the muscle with 5-0 Monocryl sutures. It is then supported with a large stent-like compression bolster dressing. These grafts develop new vascular patterns that have been observed experimentally to appear in a stable manner at a 3–4 week interval and offer the advantages of a custom-created neovascularized skin flap.¹⁴ This type of flap then avoids the use of a large, bulky myocutaneous skin paddle. When the graft maturity is established (4–6 weeks) and the maximum contracture is noted, the muscle and skin are retrieved with a circumferential incision around the graft including a 3 mm margin of thigh skin (Figure 60.7B). The skin graft, which is now a flap by definition, is tailored to fit the urethral defect including a redundant margin (Figure 60.8). The distal gracilis tendon is transected and the long muscle flap with the adherent skin graft composite is transferred on its proximal pedicle into the perineum for a proximal urethral repair (Figure 60.9).

GRACILIS MYOFASCIOCUTANEOUS FLAP

The gracilis muscle with a cutaneous component has a more limited application in urologic reconstruction,

(A)



(B)

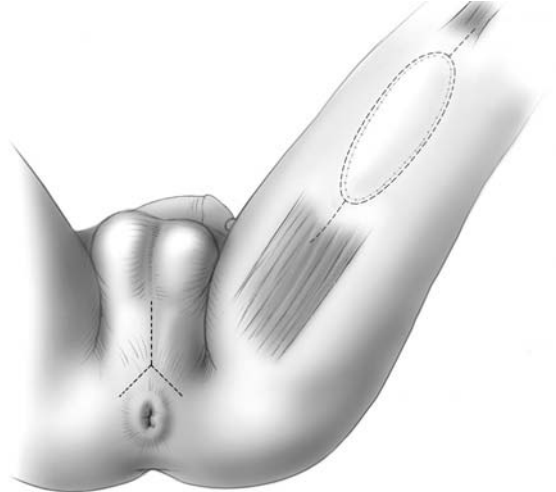


Figure 60.7 (A) The muscle is exteriorized through a 12 cm incision over its distal third suturing it to the dermis at the skin's edge. (B) The full-thickness skin graft is sutured to the edge with interrupted 4-0 Monocryl sutures completely covering the exposed muscle surface. The graft is pie crusted and quilted against the muscle. The composite is supported with a large stent-like compression bolster dressing.

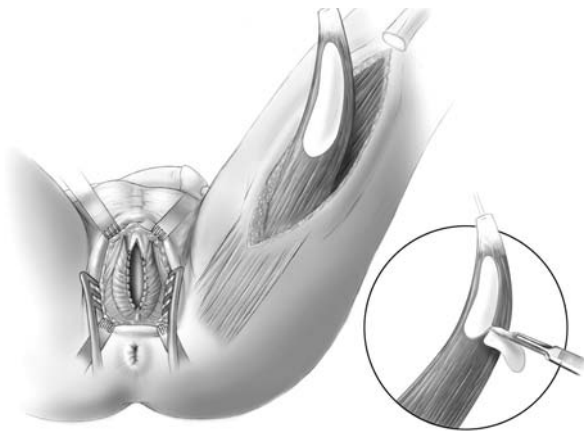


Figure 60.8 When the graft take is secure, the muscle is explored through a circumferential incision around the graft margin extending distally and proximally to expose the entire flap.

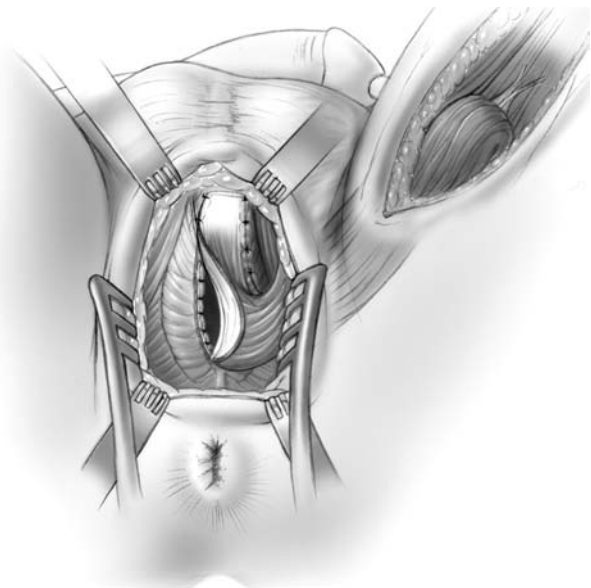


Figure 60.9 The urethral stricture is first exposed and the appropriate stricturotomy is performed. The thigh incision is extended proximally and distally, dividing the gracilis tendon near its insertion. The urethroplasty is completed by transferring the gracilis muscle with its newly added skin component through a generous medial thigh and perineal tunnel. The skin patch is sutured to the urethral edge.

but can be an invaluable adjunct when a supportive muscle and a skin cover are required. The perineal decubitis with a urethral or prostatic defect, the radiated prostatoperineal fistula following abdominoperineal rectal excision, inflammatory bowel disease with multiple urethrocutaneous fistulas, and the genital and perineal defect following debridement for necrotizing fasciitis are some indications for this flap combination (Figure 60.10). Since partial and total necrosis of the cutaneous portion of the flap occurs in 13% and 6.8% of this combined tissue transfer using the classic flap, respectively,¹⁵ a modified harvesting technique has been described by Whetzel and Lechman¹⁶ in an attempt to overcome and avoid the

hazards of retrieving an overlying skin segment that has an absent cutaneous vascularization derived directly from the muscle surface. During elevation of the muscle, the deep investing perigracilis septal fascia, including fascia of the adductor longus, vastus medialis, adductor magnus, semitendinosus, and sartorius, is included so that

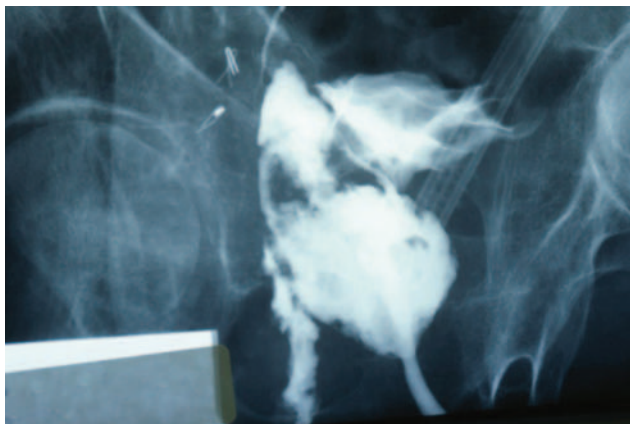


Figure 60.10 Retrograde urethrogram in a 67-year-old patient with a radiation prostatocutaneous fistula 11 years after rectal excision.

no gracilis muscle fibers are seen. The proximal end of the greater saphenous vein can be left in situ and mobilized with the flap. The approach is based on the observation that blood supply to the skin over the gracilis muscle comes primarily from vessels traveling around it, rather than through the muscle. The anterior border is the predominant route for blood vessels on their way to the skin, so the flap is designed with its center based on the anterior edge of the muscle rather than on the midline. This concept is in opposition to the original description where the blood supply was consistently and directly through the muscle by the perforators to the surface.¹⁷ This vascular pattern accounts for both muscular and fasciocutaneous vascular concepts in the gracilis environment. The fasciocutaneous component needs to be integrated into the planning of a viable musculocutaneous flap, since the vascular basis is primarily by means of the septocutaneous vessels within the septum between the gracilis and the adductor longus muscles, most of which originate from the main gracilis pedicle and travel around the muscle rather than through it to the overlying skin. This anatomic approach to the vascular anatomy of the cutaneous paddle has been validated by Chuang et al¹⁸ in head and neck reconstruction, where the gracilis has been transferred as a free flap.

OPERATIVE TECHNIQUE FOR TRANSFER OF THE GRACILIS MYOFASCIOCUTANEOUS FLAP

The patient is placed in the lithotomy position for flap transfer to the perineum, vagina, or the inguinal location with the legs in adjustable and flexible multijointed

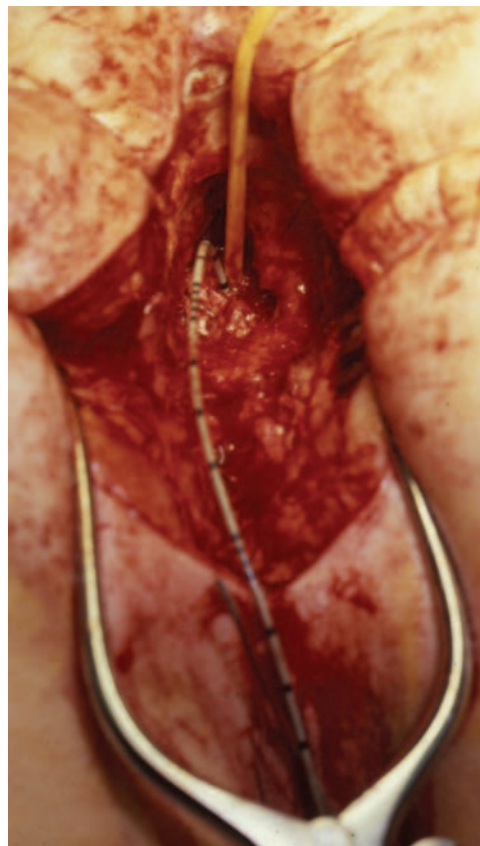


Figure 60.11 Exposure of prostatic radiation fistula and excision of radionecrotic intergluteal skin surface in prone position.

yellow-fin stirrups. This permits the knees and thighs to be flexed or straightened for the transfer after flap dissection. Cutaneous flap size is determined by measurement of the defect to be covered or the size of the space that will require the appropriate volume of muscle and de-epithelialized skin for replacement and fistula closure (Figure 60.11). Cutaneous vascular perfusion is more reliable when the size of the skin paddle is reduced to an 8 × 20 cm measurement along with excision of the distal gracilis muscle when a 'short' gracilis flap is utilized after ligating the medial circumflex femoral pedicle. A guide line is drawn initially on the unflexed thigh from the pubic tubercle to the medial femoral condyle. A large oval vertical skin island is outlined with its center over the anterior edge of the muscle in its proximal two-thirds (Figure 60.12). The distal tendon is then mobilized anterior to the semitendinosus muscle tendon. A larger flap tends to be more secure with regard to blood supply since the critical perforators have a more likely chance of being included in the flap (Figure 60.13). The anterior flap margin is dissected deep into the subcutaneous tissue to the fascia (Figure 60.14).

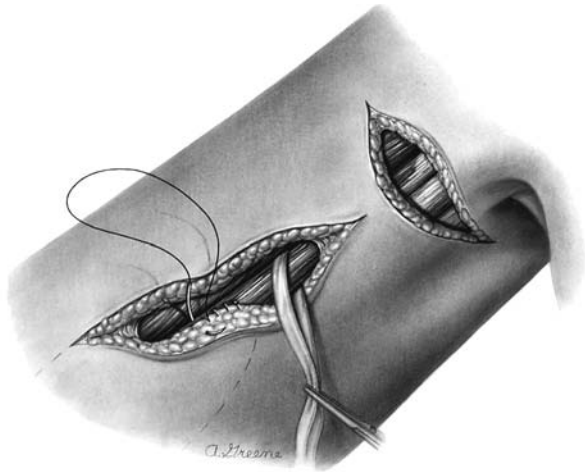


Figure 60.12 Gracilis myofasciocutaneous flap with skin paddle centered over borders of the proximal two-thirds of the muscle.



Figure 60.13 The skin margin of the flap is sutured to the fascial underside of the muscle to avoid shearing disruption of the muscular and septocutaneous perforators during elevation.

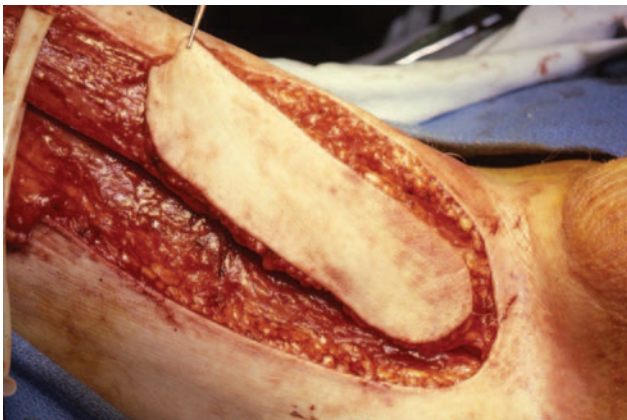


Figure 60.14 The distal tendon medial to the semitendinosus is divided and the flap is elevated after the skin flap is prepared.

The medial fascia of adductor longus and vastus medialis, adductor brevis, and semitendinosus is included with the gracilis along with all of the sartorius and all the gracilis fascia so that no gracilis muscle should be seen. This includes all the tissue between the adductor longus and the gracilis. The saphenous vein segment is included to attain the maximal rotation for vaginal and any deep perineal spaces. The skin margin is sutured to the fascia underside to avoid disruption of the muscular septocutaneous perforating vessels by shearing of the skin off the muscles during further elevation of the proximal incision. The distal tendon is divided and the flap elevated with the attached skin island proximally (Figure 60.15). The distal two minor pedicles from the superficial artery are ligated and divided. The relation of the skin to the muscle is again confirmed as it is elevated and changed if not correctly centered over the muscle. The dominant pedicle will be seen by retracting the adductor longus medially as it passes over the deeper adductor magnus. The flap is rotated on its pedicle to the defect by making a wide suprafascial subcutaneous tunnel to accommodate the flap without tension or compression.

If compression potential exists then the skin bridge is divided. If further skin paddle rotation or advancement is required at the recipient site, the legs are then brought down with some adduction and muscle shortening which provides an additional 3–6 cm in length. The thigh and perineal incisions are closed, with a suction drain (Blake) left in for 72 hours. The leg is firmly wrapped and the patient is immobilized for 72 hours and subcutaneous heparin is utilized for 7 days. If any of the surface demonstrates necrosis then early debridement with a stented skin graft is instituted. The radiated prostate cutaneous fistula has consistently been effectively closed by this approach (Fig 60.15).

The anatomic approach to the harvest of the myofasciocutaneous flap with aggressive inclusion of

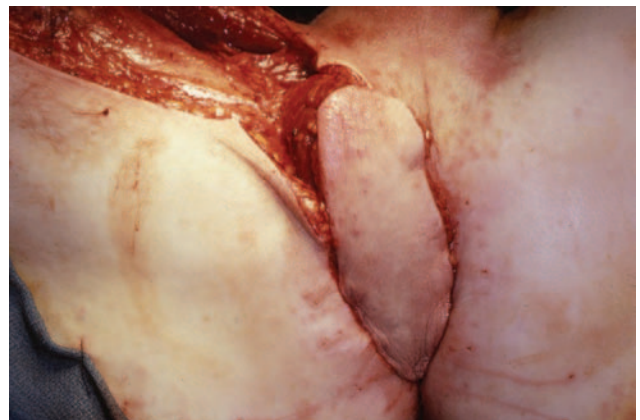


Figure 60.15 The flap is rotated on its pedicle without tension into the defect after dividing the groin skin bridge.

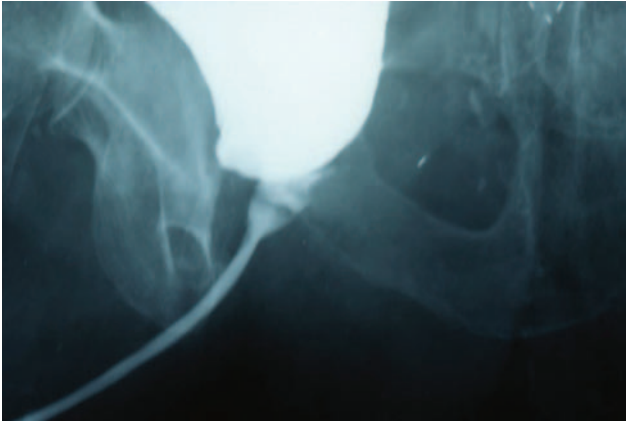


Figure 60.16 The postoperative urethrogram reveals fistula closure under an effective perineal skin cover.



Figure 60.17 The perigracilis septocutaneous perforators that come around the muscle result in a well perfused viable myocutaneous axial flap.

the perigracilis fascia creates the most reliable vascular inflow to the middle-third of the skin island (Figure 60.17). All the cases have been retrieved by preseptal debridement and a stented split thickness skin graft cover.

PERINEAL ARTERY FASCIOCUTANEOUS FLAP (SINGAPORE)

The perineal artery medial thigh fasciocutaneous flap is another concept in tissue transfer that has the potential of salvaging the complex proximal prostatomembranous and bulb stricture. It is particularly suited for the repair of radiation prostatic-membranous strictures, recurrent failed postanastomotic urethral distraction defects, and the rare rectourethral fistula associated

with a proximal stricture. The flap can be a valuable adjunct in the initial perineal and thigh coverage of defects following necrotizing fasciitis. The radiation vesicovaginal fistula has also been successfully closed by utilizing the skin cover to replace the ischemic vaginal wall. Its robust blood supply, predictable measurements, minimal donor site morbidity, and prior reported success in vaginoplasty make this flap an ideal alternative option for complex proximal urethral reconstruction. The proximal portion of the medially rotated flap increases the safety and security of the perineal cover in patients with overlying perineal skin loss, prior surgery or radiation injury in conjunction with the urethral replacement. It belongs to the class of axial fasciocutaneous flap constructs consisting of skin, subcutaneous tissue, and a well developed fascial under-surface. The flap has a defined skin territory supported by an identifiable vascular pedicle, the perineal artery which is a distal branch of the internal pudendal. The perineal artery penetrates the fascia at its base and develops a suprafascial plexus, which arborizes with the subdermal plexus and reliably perfuses the skin.¹⁹ The flap has the advantages of a simple dissection, minimal bleeding, no loss of function, and minimal bulk, making it more suitable for a smaller defect such as those seen in urethral, vaginal, and scrotal reconstructions. It can be transferred to the urethra using three different techniques of flap rotation. The onlay patch is the most commonly used for urethral repair and best designed in a transverse direction.^{20,21}

FLAP DESIGN AND TECHNIQUE OF ELEVATION FOR ONLAY PATCH URETHROPLASTY

The perineal artery, or Singapore, flap is a vertically oriented composite of skin with an underlying deep fascia and adductor epimysium measuring 6 × 15 cm with its proximal base located at the level of the mid-perineum 3 cm distal to the anal margin (Figure 60.18). The perineal artery arises just medial to the groin crease with branches to the scrotum and medial thigh skin. This circulation is richly enhanced by its arborization with the deep external pudendal, medial circumflex femoral from the profunda femoris, and the anterior branch of the obturator artery. This is a partially sensate flap innervated by the pudendal and the posterior cutaneous nerve of the thigh with good sensory perception in the mid-perineal portions of the transferred flap. The urethral stricture is exposed by a thorough ventral urethrotomy, which is started distally

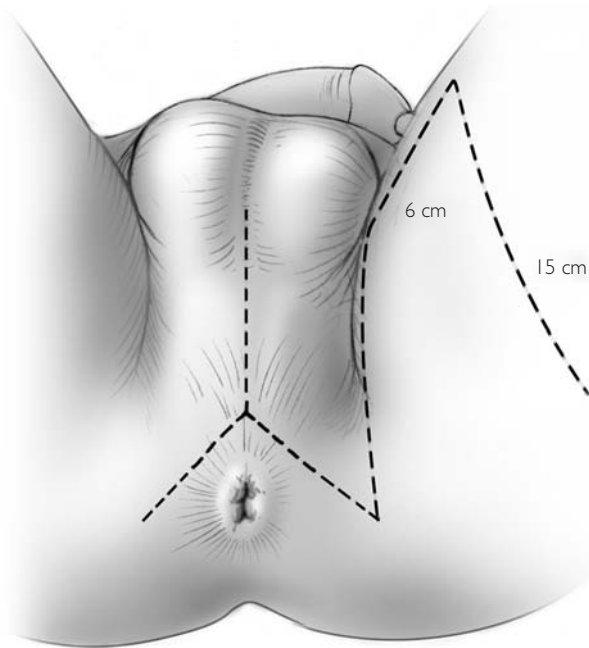


Figure 60.18 Perineal artery medial thigh flap measurements are consistently 6×15 cm with its proximal base located at the level of the mid-perineum. The medial border is the groin crease lateral to the edge of the scrotum.

with an indwelling 5Fr Fogarty vascular balloon catheter as an intraluminal guide and carried proximally to a point 2 cm beyond the balloon to establish a 30Fr proximal lumen and a 26Fr distal lumen. This flap is outlined initially with a skin marker defining the measurements with the skin on stretch and extending it, if needed, an extra 2 cm into the femoral triangle, where random circulation based skin extension occurs. The incisions are started in parallel vertical lines down to the fascia on both sides, raising the epimysium with the fascia and suturing it to the dermis to prevent shearing injury to the segmental vessels. The flap is then lifted back to its proximal transverse margin after completing the distal transverse incision. Effective blood flow is confirmed by de-epithelializing a 2–3 mm area at the distal margin to identify a bleeding dermis. The tissue bridge between the base of the flap and the urethral exposure is divided to prevent tunnel pressure effect and the potential compromise of flap circulation. This procedure permits ease of transfer to the deep proximal urethra and a lateral rotation of the scrotal and perineal tissues to help close the donor site.

A 6–8 cm transverse island is outlined at the distal edge of the flap by de-epithelializing a 3–4 cm strip of skin just proximal to the island onlay segment, leaving a thin layer of dermis to prevent ischemic injury to the transverse island (Figure 60.19). If the urethrotomy is

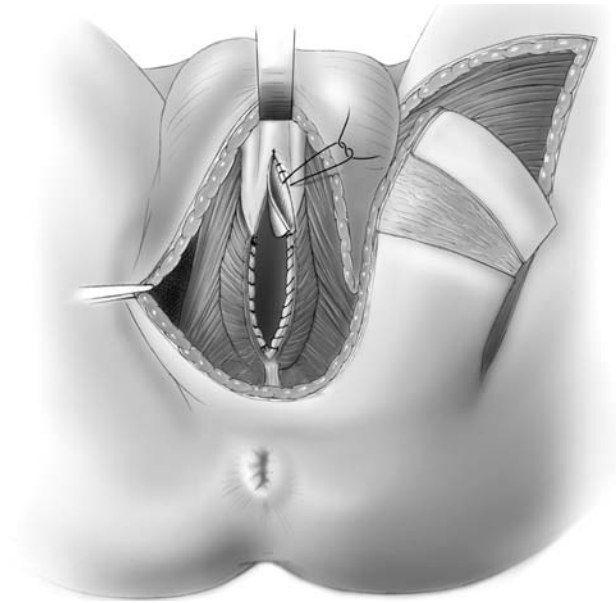


Figure 60.19 A proximal urethrotomy is performed from the distal bulbous urethra across the transsphincter segment to the prostatic apex. A buccal mucosa graft can be utilized to repair the distal portion of the bulbar stricture if the suture is longer than 6–8 cm. A distal transverse island is outlined at the distal margin of the flap and a 3 cm wide strip of skin is de-epithelialized just proximal to the island leaving a thin layer of dermis.

greater than 6 cm in length it will require an additional segment of buccal mucosa in a combined composite to repair the entire stricture. The buccal mucosa graft is always placed in the more distal portion to avoid the transsphincteric site where flaps are more likely to succeed than grafts. The flap is then rotated medially and inferiorly, and the island patch is sutured by initially placing the apical sutures at each end to establish a good fit without folds or bunching. If the proximal apex is in the prostatic floor then six 4-0 Monocryl sutures are initially placed at the site, rearmed and inserted into the inferior edge of the flap (Figure 60.20). The donor site is closed by advancing the thigh incision toward the scrotum and transferring the scrotal bridge laterally (Figure 60.21). A small suction drain exiting through the thigh incision is removed after 3 days. The urethral catheter and suprapubic cystostomy are left in for 3 weeks pending a normal voiding cystourethrogram.

GLUTEUS MAXIMUS MUSCLE FLAP FOR BULBOMEMBRANOUS URETHRAL RECONSTRUCTION

Prostatocutaneous and proximal bulbomembranous urethral fistulas and strictures may occur from surgical

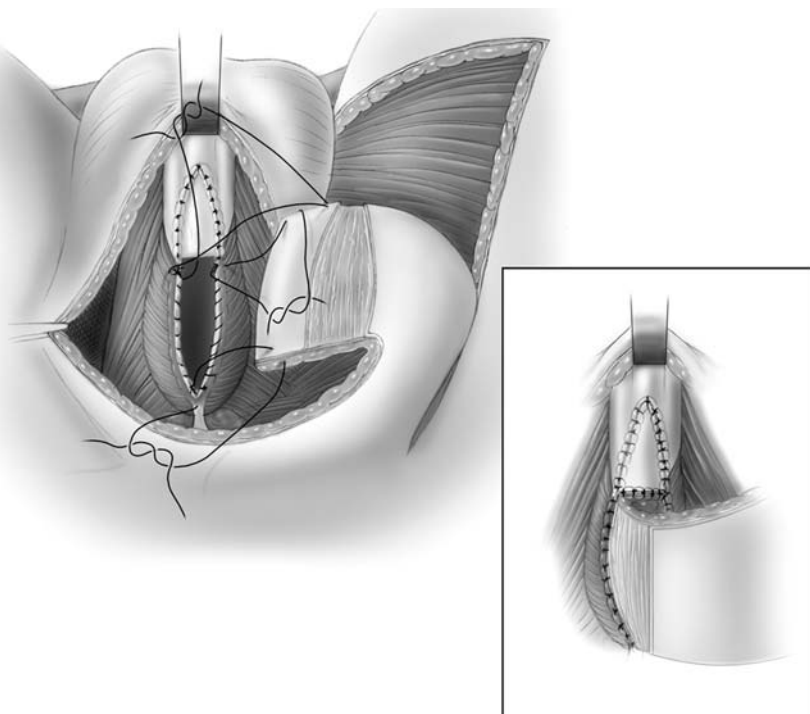


Figure 60.20 A transverse island is rotated medially and inferiorly, and the island of skin is applied to the urethrotomy defect and sutured with running 4-0 Monocryl sutures. The distal edge of the island flap is approximated to the proximal margin of the buccal graft completing the combined reconstruction.

trauma following abdominoperineal resection of rectum for cancer and inflammatory disease, as a delayed phenomenon associated with adjunctive radiation therapy, or the result of a pressure induced decubitis with associated perineal skin loss. This recalcitrant problem requires a large, reliable muscle flap that will buttress the repair, fill in the non-collapsible retrovesical dead space and tissue loss surrounding the fistulas and offer a good blood supply to a rigid fibrotic tract and a buccal graft onlay. There needs to be a sufficient tissue bulk for covering the perineum and intergluteal space and a well vascularized surface to assist the closure of the defect in the face of impaired wound healing. This can be accomplished by a number of muscle flaps including transabdominal transfer of the rectus abdominus bilateral coapted gracilis muscle flaps combined with a semitendinosis, a gracilis myofasciocutaneous flap, or a free latissimus dorsi flap. Our use of unilateral or bilateral inferior gluteus maximus has been the most effective for this pathology. The anatomic insights gained over the past decade have resulted in the development of a number of gluteus maximus muscle flap designs which permit preservation of function and the ability to transfer a large muscle bulk to the deep perineum and presacral space.²² The inferior gluteus maximus or lower segment of this muscle based on the inferior gluteal artery vascular pedicle permits rotation of the muscle into an intergluteal, subcoccygeal, and perineal space without incurring

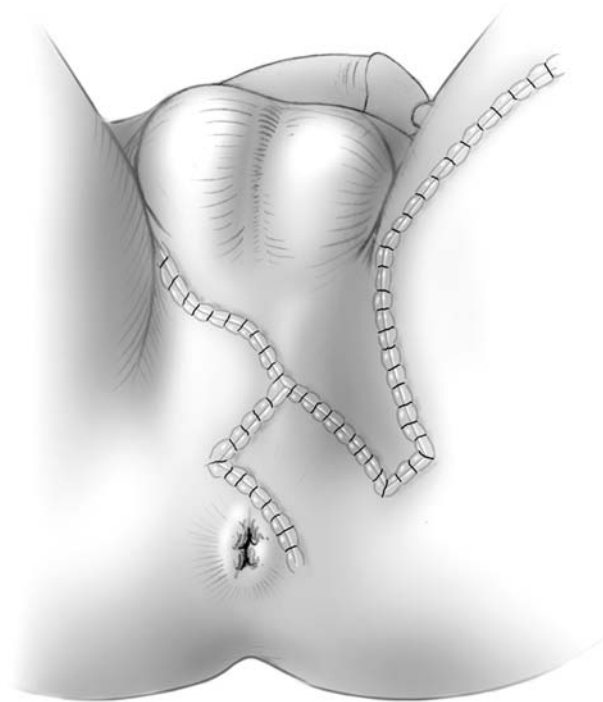


Figure 60.21 Closure of the perineum and donor site is accomplished by rotating the inguinal and scrotal bridge laterally into the thigh defect and advancing the inferior margin of the thigh incision toward the groin. No donor site morbidity has been noted.

impaired motor function or contour deformity of the buttocks.²³

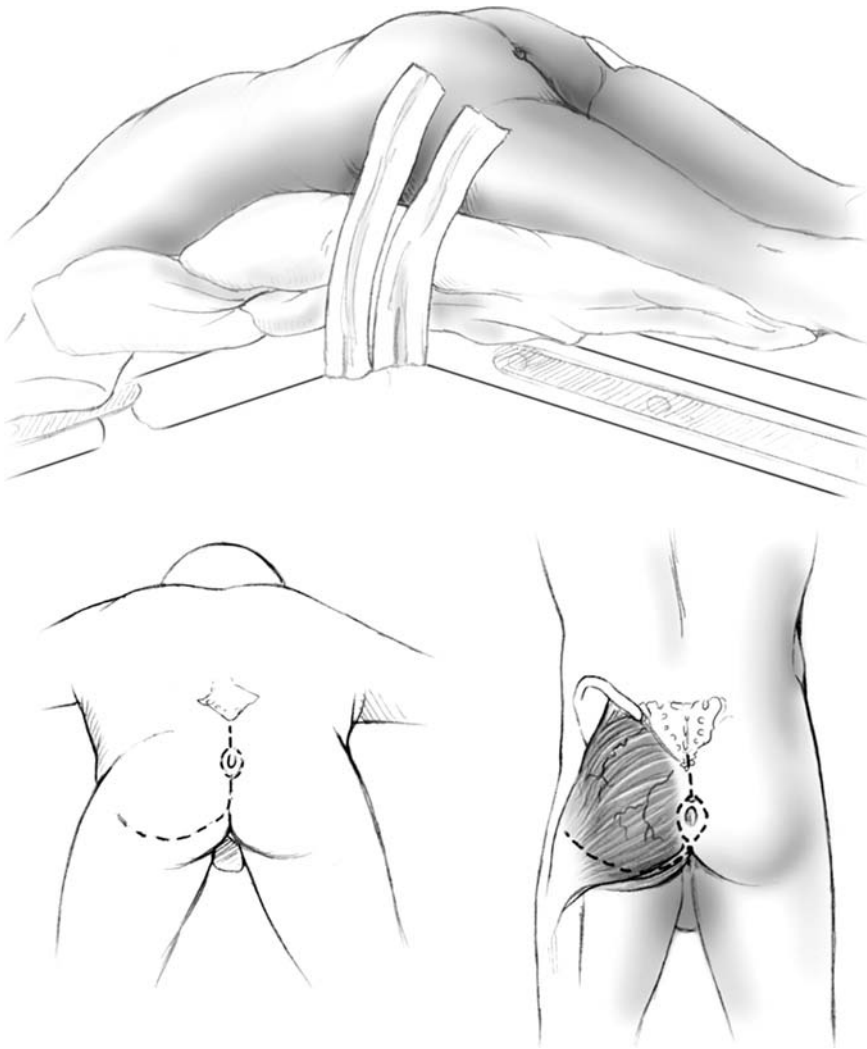


Figure 60.22 The patient is placed in the prone position with the waist and pelvis flexed. The legs and feet are protectively padded and chest rolls are placed under the chest and pelvis to prevent pressure point injury. The fistulous tract is excised with the indwelling stent. The incision is extended in the mid-perineal line in both directions and laterally to expose the surface of the inferior gluteus maximus. The inferior segment of the muscle is identified after the horizontal component of the incision is made.

ANATOMY AND CLINICAL APPLICATIONS

The gluteus maximus is a large, quadrilateral muscle that forms the prominence of the buttocks. It measures 24×24 cm on average and arises from the posterior gluteal line of the ileum and the sacrum, the side of the coccyx, the aponeurosis of the sacrospinalis, the sacrotuberous ligament, and the fascia over the gluteus medius muscle. The fibers from a diffuse origin course laterally and inferiorly to insert into the ileotibial tract and the gluteal tuberosity of the femur. The muscle is nourished by the superior and inferior gluteal arteries, which are branches of the internal iliac arteries. There are two minor vascular pedicles, which anastomose freely with the gluteal vessels. These are the first perforators of the profunda femoris artery and vein, and the intramuscular branches of the lateral circumflex femoral artery from the profunda. The first perforator enters the muscle adjacent to its insertion and the two

or three intramuscular branches enter beneath the inferior gluteus muscle insertion. The superior and inferior gluteal arteries pass above and below the piriformis muscle and are located 4 cm medial to the midline (Figure 60.22). The inferior gluteal nerve (L5–S1) courses through the sciatic foramen, accompanies the inferior gluteal artery medial to the sciatic nerve, and enters the gluteus maximus muscle on its deep surface at the level of the piriformis muscle, where it supplies motor innervation to the entire muscle.

Loss of muscle function does not become evident in casual activities such as easy walking or standing because other muscles will compensate for its loss. The gluteus maximus extends and rotates the thigh laterally and is important for more forceful activities such as running, climbing, and jumping. The superior or inferior half of the muscle may be elevated as a flap without loss of function if the other half is intact. The muscle segment can be rotated to cover the sacrum where the dominant pedicles enter the muscle very

close to the fibers of origin from the sacral edge. The muscle is split into two segments and the inferior portion is utilized primarily for perineal and vaginal reconstruction. The lower distal portion is adjacent to the intergluteal and perineal space, making it an optimal skeletal muscle flap for repair of this portion of the urethra and for obliteration of the pelvic space.

TECHNIQUES OF GLUTEAL MAXIMUS REPAIR OF PERINEAL URETHROCUTANEOUS FISTULAS AND STRICTURE

The patient is initially cystoscoped in the lithotomy position, at which time any fistulous tracts are cannulated with a ureteral catheter and the bladder drained with a urethral catheter. The patient is then placed in the prone position with the waist flexed and the legs separated. Protective padding is used for the legs and feet, and chest rolls are placed to prevent pelvic and breast compression. The lateral edge of the sacrum and greater trochanter are initially identified and marked as respective origin and insertion of the gluteus maximus muscle. The fistula tract is excised by making a circumferential incision and extending it cephalad and caudal along the perineal midline in the intergluteal groove. The intergluteal midline cleft is incised from the scrotum to the coccyx deep to the ventral urethral and prostatic surface. The incision is extended horizontally along the inferior gluteal crease to expose the superficial surface of the muscle. The dissection proceeds cephalad under the coccyx and laterally down the pelvic side wall. More exposure can be achieved by extending the incision parasacrally. The urethra is identified and the lateral fibrous and radiated tissues are excised. The overlying skin on the gluteus muscle is retracted upward and laterally. The coccyx is resected and the prostatic surface exposed. More sacral bone is removed if there is poor exposure or obvious radionecrotic bone involvement. A prostatic fistula is closed with a buccal mucosa graft following exposure and lateral retraction of the levator ani muscle. A proximal urethral stricture can also be repaired with a buccal mucosa onlay in a ventral position followed by support to both grafts with a muscle surface. This well vascularized muscle will overcome completely the adversity of the radiated pelvis.

To elevate the inferior half of the gluteus maximus after exposure of its superficial surface, the muscle is split at its mid-portion. The inferior half of the fibers of insertion are divided and separated from the ileotibial

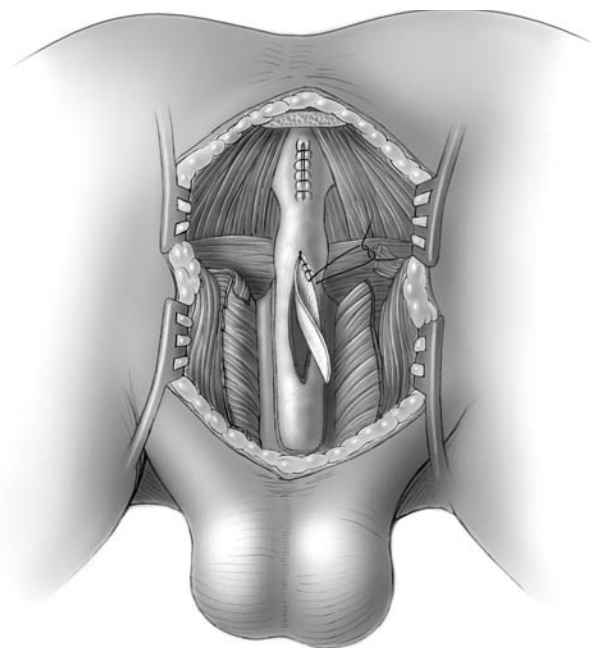


Figure 60.23 The prostate and proximal urethra are exposed through an intergluteal dissection following excision of the fistula tract. A buccal mucosa patch onlay is placed ventrally to repair a proximal stricture and prostatic fistula.

tract and the gluteal tuberosity and the muscle is mobilized from lateral to medial, identifying the inferior vascular pedicle. The origin can be completely detached from the sacrum without endangering the blood supply, if needed. The piriformis muscle is the key reference point in locating the sciatic nerve deep to the gluteus maximus. With the sciatic nerve carefully preserved and the location of the gluteal vessels confirmed, the muscle can be split to the level of the sacrum in preparation for transfer (Figure 60.23). A 10 × 20 cm flap can be retrieved based on the inferior gluteal artery. Gradual detachment of the inserting fibers of the muscle on the ileotibial tract, intermuscular septum, and the lesser trochanter of femur can be readily performed once the underlying structures are identified. Partial release of the gluteus origin from the sacrum will facilitate further flap transposition, which can be easily moved an additional 5–9 cm. The distal flap surface is then advanced into the perineal defect from the buttock and fixed to the periurethral fascia, completing the buttress effect over the urethral and prostatic graft and fistula (Figure 60.24). With adequate mobility, the muscle can also be placed under the sacral roof to completely obliterate the entire retroprostatic and urethral compartment (Figure 60.25).

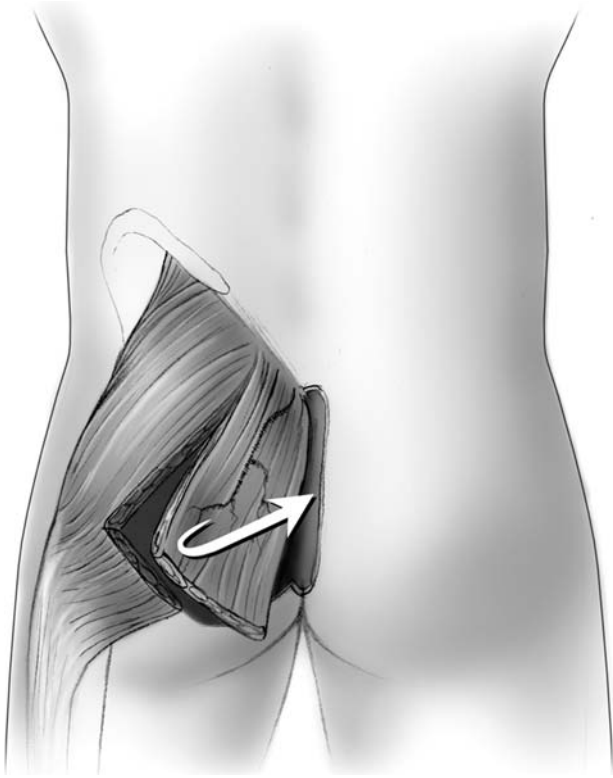


Figure 60.24 To elevate the inferior half of the gluteus maximus, the muscle is split and mobilized initially from the lateral to medial identifying the inferior gluteal vascular pedicle. The inferior half of the fibers of insertion are divided and the remainder of the muscle is split to the level of the sacrum preparing it for rotation to the perineum.

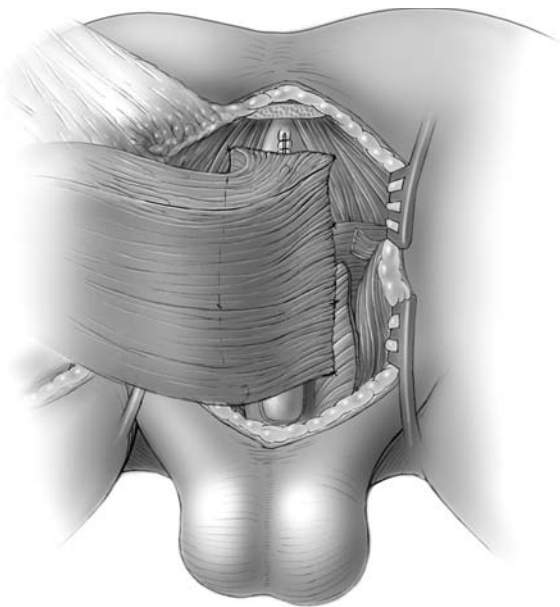


Figure 60.25 The distal muscle flap edge is advanced medially into the perineal defect obliterating the rectourethral and prostatic space from the sacrum to the perineal skin edge where it is fixed to the periurethral and periurethral fascia.

The donor site can be closed by mobilizing the contralateral skin edge and turning the skin and subcutaneous tissue over in a medial direction and suturing it to the contralateral skin edge. It is rarely necessary to place a skin graft for exposed muscle since lateral buttock and inferior subcutaneous thigh skin dissection will allow closure without tension.²³ If the muscle does not reach the buccal graft surface, a gracilis or semitendinosus muscle can be retrieved in the prone position and transferred in the space under the inferior gluteus maximus. The gluteus maximus muscle or musculocutaneous flap provides reliable support and buttressing of recalcitrant prostatic and urethrocutaneous fistulas, and urethral strictures in patients who have undergone a prior proctocolectomy. The technique advances a large bulk of well vascularized muscle, which permits complete obliteration of perineal and intergluteal spaces that have been injured by prior radiation or tissue loss. This is not an expendable muscle but proper mobilization of the inferior gluteal segment with preservation of the superior segment, loss of strength in extension and abduction of the hip can be prevented permitting the use of a local muscle flap with minimal donor site morbidity.

CONCLUSION

The muscle assisted skin graft composites, the gracilis muscle transfer variation, the Singapore medial thigh flap, and the inferior gluteus maximus muscle flap are reliable extragenital axial flaps that are suitable for local genital skin substitution techniques. They are all simple in design, relatively easy to harvest, possess reliable vascular and cutaneous landmarks, and are transferred easily to the urethra and the perineum without tension and without creating any significant donor site morbidity. They are all particularly valuable resources in the management of recalcitrant pathology or the presence of wound healing impairment such as radiation or other adverse conditions that would jeopardize genital skin graft and flap survival. These expendable muscle-and-tissue covering flaps will not result in impaired motor function if careful attention is paid to the details of their retrieval. Other axial flaps that are available as an enhancing support system include the posterior thigh fasciocutaneous, rectus abdominis, rectus femoris, semimembranosus, semitendinosus, and latissimus dorsi free flap, all of which require more complex retrieval techniques. The only consistent option for repair of the complex urethral stricture pathology in patients who have undergone numerous

failed prior procedures in the proximal and posterior urethra is the combined use of a ventral buccal mucosa, posterior auricular Wolfe, or penile skin graft supported by a transferred skeletal muscle surface.

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61 Contemporary management of rectourethral fistula

Leonard N Zinman

Rectourethral fistulas have been an uncommon, but increasingly occurring, complication of radical prostatectomy and radiation therapy of organ confined prostate cancer, and present a unique surgical challenge for the reconstructive urologic surgeon. The basis of the challenge is the presence of the disorder in an inaccessible space, containing sphincter activity and erectile related anatomy along with the potential of creating anosphincter dysfunction and impotence in the presence of a fibrotic and adherent rectoprostatic plane.

Historically, this complication has been most often seen following surgery for benign prostatic obstruction, most commonly after perineal adenectomy and perineal prostatic biopsy.^{1,2} With the unprecedented volume of prostatic cancer seen over the past two decades, the primary etiology has dramatically shifted to radical open and laparoscopic prostatectomy, brachytherapy, and salvage cryotherapy and high intensity focused ultrasound (HIFU) for recurrent disease after external beam radiation. The incidence of radiation induced fistulas reported prior to 1997 was 3.8%, while the incidence of those appearing after 1998 increased remarkably to 49.6% of all published series of rectourethral fistulas, establishing the contemporary contribution made by this rekindled increasing popular modality.³ Rectal injuries occurring during the course of open retropubic and perineal prostatectomy for cancer have varied from 1 to 11%.^{4,5} Laparoscopic and robotic radical prostatectomies are now acceptable and reproducible techniques for managing localized prostatic cancer with an overall reported incidence of rectal injury and rectourethral fistula between 0.8 and 3.3%.^{6,7} The rectal injury that occurs during open radical prostatectomy develops while transecting across the rectourethral muscle at the very start of the procedure, while those developing after laparoscopic radical prostatectomy are noted at the base of the prostate in a more proximal posterior plane between the seminal vesicles and rectum, producing a fistula in a more caudal location. The risk factor for this complication is periprostatic fibrosis from prior prostate or rectal surgery, numerous repeated biopsies, radiation, or prior hormone therapy, which may mask the anatomy with a periprostatic fibrosis and locally advanced T3 and T4

tumors which may produce an intense desmoplastic reaction or extension of disease. This higher risk group needs a prior bowel preparation anticipating the potential for a rectal laceration. Most rectal injuries are identified intraoperatively and can be successfully managed by a careful one-layer closure with routine transfer of an interposing flap of omentum, the present approach to this surgical misadventure. Most rectal injuries are identified intraoperatively and can be successfully managed by a careful one-layer closure with transfer of an interposing flap of omentum, rectal sphincter dilatation, and a low residue diet, but the key to prevention of the development of a fistula is a meticulous tension-free, watertight vesicourethral anastomosis and a 4–5-week period of catheterization.⁸ The use of fecal diversion can be crucial for large rectotomies (>2 cm), poorly prepared colon, or a tenuous closure, and this should be managed by an immediate loop ileostomy.

DIAGNOSIS

Most patients with rectourethral fistulas present with the classic triad of pneumaturia, fecaluria, and the rectal passage of urine along with a smaller number experiencing recurrent urinary tract infection with multiple organisms and a minor degree of metabolic acidosis with an elevated serum chloride. Radiation and cryogenic fistulas may present with severe rectal bleeding, pelvic and intra-abdominal sepsis, osteomyelitis, necrotizing fasciitis of the perineum and thigh, or the development of severe rectal pain, which dramatically resolves when the rectal wall breaks open and fistulizes. The diagnosis of rectourethral fistulas is never subtle but the location can be elusive and requires careful endoscopic and radiologic scrutiny. The rectal examination will usually reveal the defect on the anterior rectal wall within easy reach of the examining finger. An anesthetic examination which includes cystogram combined with a retrograde urethrogram (up and downogram) and cystourethroscopy will define some of the smaller lesions which may also require injection fistulography. Sigmoidoscopy

and colonoscopy will localize the level of the fistula, identify anal sphincter integrity, rectal wall compliance, or an irreversible loss of functional potential and the extent of radiation damage. This will help determine the selection for a reconstructive as opposed to an extirpative management. The elusive lower rectal and trans-sphincter fistulas secondary to Crohn's disease or an anterior rectal space infection may require a magnetic resonance imaging (MRI) study in an axial and sagittal plane. This type of fistula needs to be visualized in the prone position through a transanal examination. The presence of a bladder neck contracture, a bulbomembranous stricture, and urinary incontinence will alter the surgical approach and needs to be identified since they are often associated with this pathology.

FECAL DIVERSION

The use of fecal diversion to protect the repair of the fistula has not been consistently advised since the role of this very important adjunct is not fully understood. It should be mandatory in cases of a tenuous closure, prior failed attempts to repair it, complex cases secondary to radiation, cryotherapy, and salvage therapy, or a large fistula that does not lend itself to primary direct approximation without the use of such adjuncts as patch graft onlay and an interposition muscle flap. There are no data to confirm a higher rate of success employing a protective stoma routinely, but our bias is to make fecal diversion an integral part of the reconstruction during initial evaluation along with a suprapubic cystotomy, since failure to repair this lesion creates a potential cascade of injury to the functional aspect of both bowel and bladder function. Early fecal diversion will decrease the chance of pelvic and intra-abdominal sepsis and osteomyelitis, decrease perifistula proctitis, and inflammation, and help alleviate rectal pain and facilitate fecal drainage.⁹ In the presence of a functionally intact anal sphincter with preserved continence and a compliant rectum, a laparoscopic ileostomy will permit a less invasive readily reversible form of diversion without the need for a laparotomy to restore continuity. When there is a clearly irreversible injured anal sphincter, an end sigmoid colostomy should be employed, since this form of diversion offers a better quality of life. The smaller surgically created fistulas or those rectal injuries identified intraoperatively and repaired immediately are more likely to close spontaneously with combined urinary and fecal diversion. The temporary loop ileostomy will also permit mobilization of the

colon for colonic advancement if a proctectomy and coloanal anastomosis is required.

TREATMENT

Rectourethral fistulas are due to a myriad of etiologies but the key impact on selection of surgical options is whether radiation therapy, cryotherapy, or other comorbid complex factors such as repeated attempts at closure have occurred. A wide variety of surgical procedures have been described to close rectourethral fistulas, reflecting the uncertainty with which surgeons have approached this uncommon and relatively inaccessible lesion. Munoz et al described 40 different approaches to the surgical care of this entity pointing out the lack of consensus about which surgical technique is appropriate and the need to individualize therapy.¹⁰ Several principle and adjuncts are critical to the successful closure of this entity with a minimal recurrence rate. These include a proper timing interval from time of fistula onset to time of repair. In those of surgical or traumatic origin a 3–4-month waiting period following diversion with the security of an adequate nutritional status and the resolution of all sepsis should first occur. In the event of a radiation or cryogenic created fistula, tissue necrosis and obvious inflammatory change need to be eradicated and an optimal time interval of 6 months to 1 year may be required. The role of hyperbaric oxygen as an additional adjunct is unclear, but it has appeared to aid in closure of vesicovaginal fistulas of radiation therapy for gynecologic malignancies and should therefore be employed selectively in the early phase of any radiation induced fistula.¹¹

The optimal position for surgical repair is a dorso-lithotomy exposure of the perineum, genitalia, lower abdomen, and both thighs, since that permits cystoscopy and cannulation of the fistula, access to the abdomen for the potential of fecal diversion or proctectomy and a coloanal anastomosis, the ability to repair any coexisting urethral strictures, and the availability of a number of potential interposition flaps.

The multitude of effective techniques designed to treat rectourethral fistulas are essentially based on personal surgeon bias and comfort with a particular approach with a focus on simplicity of exposure and potential morbidity. The surgical options, however, should be selected based on the complexity and etiology of the lesion.¹² These include a transluminal/transanal, transanosphincteric, anterior perineal with routine use of an interposition gracilis muscle flap, or a combined

transabdominal perineal with muscle interposition in patients who have irreversibly injured rectum that cannot be repaired without proctectomy and a coloanal anastomosis or a permanent fecal diversion.^{3,13}

TRANSLUMINAL MANAGEMENT OF NON-RADIATED SURGICAL OR POST-TRAUMATIC FISTULAS

Transluminal/transanal approach

The transanal technique for the management of non-radiated surgical or post-traumatic fistulas involves a transluminal exposure of the fistula preferentially with a full-thickness anterior rectal wall advancement technique as proposed by Parks and Motson.^{14,15} This repair should be restricted to fistulas of less than 5 mm located no more than 5 cm from the anal mucosal margin. Rectourethral fistulas at this site are uncommon and most often seen secondary to inflammatory bowel disease with the occasional post-traumatic fistulas following instrumentation, or urethrotomy of the bladder neck after a radical prostatectomy. This approach offers an excellent view of the anterior rectal wall and the fistula, making it readily accessible for operative closure. An 18 Fr Foley catheter is first placed before turning the patient. The procedure should be performed in the prone position with the buttocks retracted by tape to the table edge. The anal sphincter is gradually dilated to three finger breadths and a Ferguson retractor inserted dorsally with two small deaver retractors placed laterally. The fistula is cannulated with a #5 ureteral catheter and the fistula margin excised including some rectal mucosa on the inferior edge of the fistula. A transverse incision is made from each lateral edge of the fistula into the rectal wall and a flap of full-thickness rectal wall is developed by dissecting into the plane between rectum and prostate. The urethral margins are sutured with interrupted 4-0 Monocryl and the flap of rectal wall advanced downward over the fistula and sutured to the lower border of the rectal incision followed by a mucosal closure with running 4-0 Monocryl.

The obvious advantages of this technique are simplicity of approach, limited postoperative morbidity without an external incision, no disturbance of incontinence and impotence, while achieving closure of the defect with multiple layers and non-overlapping suture lines. The disadvantages of a transanal repair include limited instrument maneuverability, potential injury to the overstretched anal sphincter, and the complete lack of access to an interposition flap of

tissue. The reported success of this procedure varies between 60 and 80% leading to a significant incidence of the need for secondary closures.^{14,16,17}

York-Mason transluminal posterior transanosphincteric approach

This procedure has been the most widely used technique for repair of rectourethral fistulas in the past decade. It was first reported by Bevan in 1917 for removal of low rectal tumors and rediscovered by York-Mason in 1969 for closure of a rectourethral fistula.^{18,19} The approach allows rapid access through unscarred tissue with provision for a wide working space, making it relatively easy to expose the fistula and manipulate instruments. The posterolateral rectal innervation, urinary continence, and potency are consistently preserved by maintaining a midline sagittal dissection and avoiding the lateral pelvic and pararectal space. There is a low rate of recurrence and it has been firmly established that a transected normal anal sphincter, if carefully placed in the midline with meticulous tagging of each muscular component, which is anatomically restored, will ultimately result in complete fecal continence. Renschler and Middleton reported the largest experience with the longest follow-up of 24 patients managed by this approach with three recurrences. They appropriately emphasized the need to carefully restrict this one-stage procedure to the smaller surgically created lesion, especially the fistula that follows radical prostatectomy and exclude patients who have anorectal dysfunction or impaired wound healing potential secondary to radiation.²⁰

The major disadvantage of this procedure is the inability to use it in the repair of large complex fistulas that may require an interposition pedicle flap, to perform concurrent urethral reconstruction or the adjunct of a urethral patch onlay for larger defects that do not allow primary closure. A modification of the York-Mason technique was introduced by Al-Ali in 1997 when he combined the same transrectal exposure with an anterior Parks type rectal advancement flap in 11 patients undergoing dual diversion with a completely successful outcome. This may permit a more consistent secure closure in the absence of an interposition buttress flap.²¹

Anterior perineal approaches

The procedures of choice for consistently successful repair of rectourethral fistulas of all etiologies are anterior

perineal approaches involving the routine use of a gracilis muscle buttress. We selectively applied one of three techniques for repair of 82 patients with rectourethral fistulas from 1980 to 2007 with no recurrences in the non-radiated uncomplicated case. The specific procedure selection was based largely on fistula etiology, size, history of radiation, prior failed attempts at closure, and the need to reconstruct concomitant urethral or bladder neck disease.

Anterior perineal anal sphincter preserving approach with an interposition flap gracilis muscle transfer

An anterior sphincter preserving traditional perineal approach through a classic inverted 'U' shaped incision has been utilized in patients with rectourethral, bladder neck, or prostatic fistulas of surgical or traumatic origin as well as complex ones, due to radiation or cryotherapy. Young and Stone in 1917 first used a perineal exposure with a wide dissection, separating the rectum from the urethra and prostate, dividing the fistula after extensive rectal mobilization and performing rectal excision followed by a colocolic anastomosis.²² Goodwin et al modified this procedure in 1958 by using an anterior perineal space dissection, closing the defects and interposing a levator ani muscle successfully in patients with acquired rectourethral fistulas.²³ Subsequent interest in the use of the interposition flaps has further enhanced the successful outcome of patients managed by the perineal approach and should be routinely employed in the complex cases where a wide separation is required and sufficiently large muscle flaps are interposed.^{12,16,24}

The procedure is performed with the patient in a moderately exaggerated dorsal lithotomy position utilizing an inverted 'U' shaped incision from midperineum to ischial tuberosities. A midline dissection above the external sphincter is maintained without a lateral or posterior extension separating the rectum, prostate, and subvesical surface up to the peritoneum. This type of dissection will prevent injury to the innervation of the rectum, anal sphincter, and penile corpora, thereby preserving potency and urinary continence, and should also be used in the smaller fistulas of surgical or traumatic origin. These defects can be repaired by primary closure with direct approximation of the urethral side with one layer of interrupted 4-0 Monocryl and a rectal closure in two layers with interrupted 3-0 Vicryl. The key to success in this repair is interposition of a viable tissue flap between rectum and urethra. The gracilis muscle flap provides the ideal structure with its proximity to perineum, it is an expendable feature without any functional loss, with a very dependable vascularity and of

sufficient size to fill the perineal space, making it our procedure of choice.

The perineal approach is uniquely suited to help manage a subset of patients with complex fistulas that were not amenable to a primary layered closure, but could readily be adequately explored through a classic anterior perineal approach with preservation of the anal sphincter. This type of fistula occurs following external beam therapy, brachytherapy, cryotherapy, salvage maneuvers after external beam radiation, and recurrences following prior failed repair. They are complex by virtue of an etiology that created impaired wound healing, a large size defect (2–6 cm) that precluded primary closure, and after prior failed attempts at closure resulting in a fibrous hypovascular space with loss of surgical planes, or were associated with the comorbidity of a urethral stricture, incontinence, or rectal sphincter injury. These large complex lesions require a wide mobilization of the rectum with lateral space dissection and aggressive debridement of the fistula margins (Figure 61.1). The rectum is widely mobilized and preferentially closed transversely with a two-layer closure to prevent anal stenosis. A tailored buccal patch graft retrieved from the inner cheek is placed on the urethral or prostatic floor defect (Figure 61.2) as these openings will not permit direct suture closure of the fistula edges.^{12,25,26} A radiation bulbomembranous urethral stricture can also be repaired at the same time by extending the urethrotomy ventrally and adding a second buccal mucosa strip as a ventral onlay to augment the urethral lumen (Figure 61.3). These grafts would not survive this unfavorable radiated, hypovascular environment without a well vascularized muscle flap. The gracilis muscle, an expendable adductor of the thigh, can be readily transferred through a capacious tunnel into the anterior perineal space where it is securely anchored and spread fixed against the graft in a tension-free state (Figure 61.4). By incising the surface membrane (epimysium) the muscle width can be increased to effectively cover the graft and the vesicourethral surface, separate the rectal and urethral suture lines, and fill in any existing dead space. The muscle flap becomes essentially the recipient bed for the graft and is largely responsible for the consistently successful closure of the complex rectourethral fistulas produced by the effects of radiation and cryotherapy (Figure 61.5). Bilateral gracilis muscles with fused medial borders have been used in nine of 37 (24%) patients with larger defects, bulbomembranous strictures requiring additional buccal mucosa graft and a larger perineal space that requires a larger muscle volume.

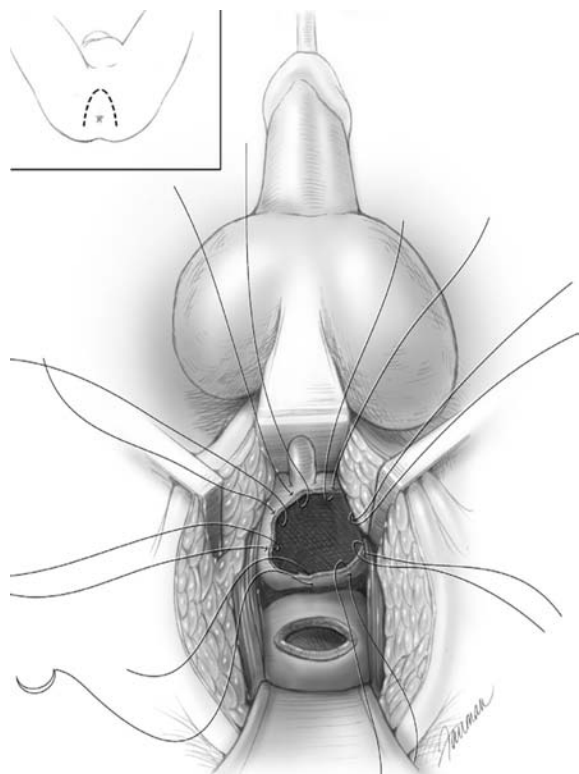


Figure 61.1 Large complex radiation or recurrent fistulas are repaired through a wide anterior perineal exposure using an inverted 'U' shaped incision. The fistula margin is aggressively debrided after careful midline separation of rectum and urethra to the level of the peritoneal cul de sac.

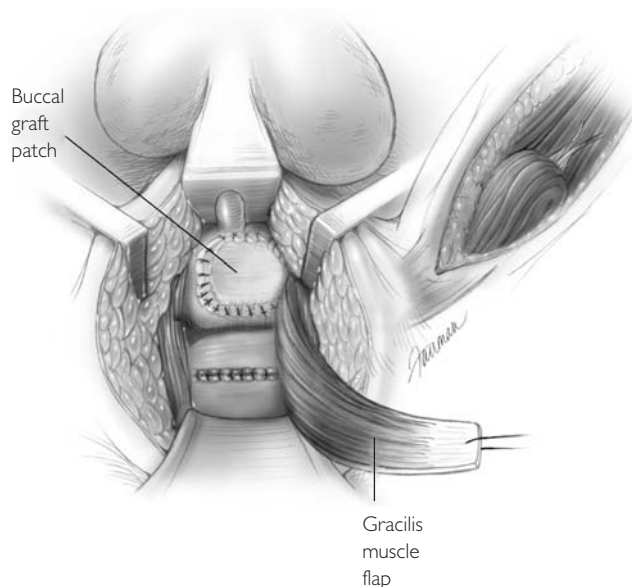


Figure 61.2 The rectum is closed if tension is absent in a transverse direction to avoid stenosis. The urethral defect is repaired with a tailored buccal graft and a gracilis interpositional muscle flap is transferred from the thigh across the inguinal crease with a wide tunnel to prevent compression of the circulation.

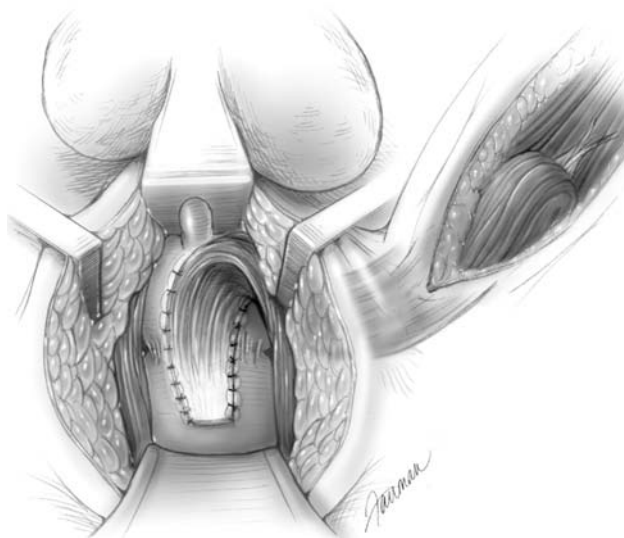


Figure 61.3 A prostatic membranous or bulbous urethral stricture is managed by extending the urethrotomy and repairing this with a ventral buccal graft onlay.

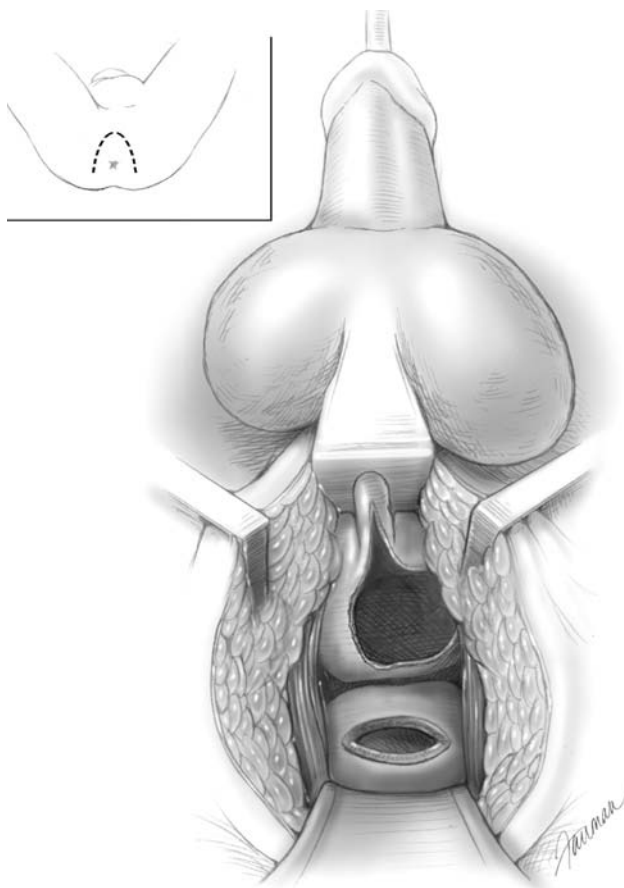


Figure 61.4 Two separate but juxtaposed grafts may be required and can be retrieved from both cheeks with minimal morbidity.

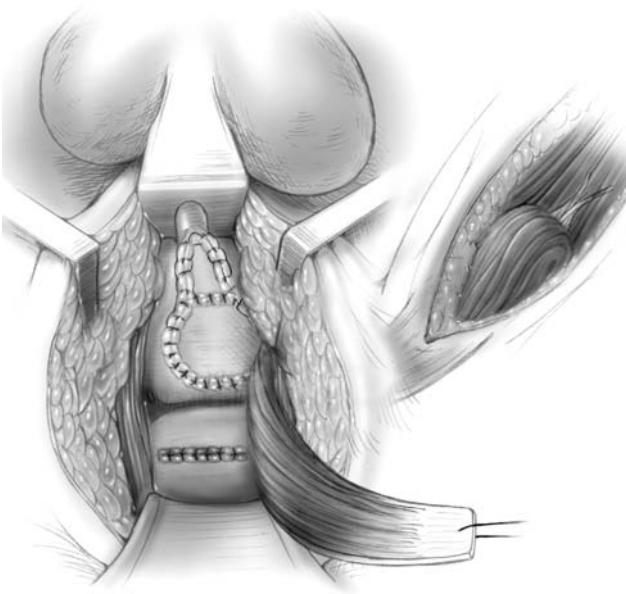


Figure 61.5 The gracilis muscle needs to be fixed against the undersurface of both grafts by turning the graft on itself as it exits the tunnel.

RESULTS OF RECONSTRUCTION OF COMPLEX RECTOURETHRAL FISTULA

Rectourethral fistula closure was undertaken in 37 patients who presented to our institution following radiation brachytherapy, or the combination of external beam radiation and salvage brachytherapy, cryotherapy, or HIFU for prostate cancer. We consistently approached the lesion through an anterior perineal technique utilizing a buccal mucosa patch graft to repair the prostatic urethral defect, a primary two-layer closure of the rectum, and the transfer of a unilateral or bilateral gracilis interposition muscle flap. Four of the patients with bilateral flaps underwent removal of the rectum due to irreversible radiation injury. Three of these patients had permanent sigmoid colostomy, and one had a successful coloanal anastomosis.

Thirty-one patients with large complex defects successfully underwent fecal undiversion at anywhere from 3 months to 2 years after initial diversion. At the time of writing, two patients were still waiting with a closed fistula but with an open perineal wound and a secondary sinus. Two patients had delayed development of an anterior prostatic fistula with retropubic sepsis and osteomyelitis at 1½ years following the successful closure of the rectourethral fistula and were subsequently repaired by a retropubic closure of the prostatic defect with an anterior bladder wall flap, pubectomy, and a rectus abdominis muscle flap, followed 1 year later with insertion of an artificial urinary sphincter (AMS-800).

Two patients had some fecal soiling which was socially acceptable, and one patient had anal stenosis managed by periodic dilatations and the use of stool softeners. In four patients, concomitant urethral reconstructions were stable with patent lumens. Two patients with bulbous urethral strictures were managed conservatively and one underwent continent stomal diversion. One patient had a colon conduit but with normal rectal function. Concurrent urinary incontinence was present in seven patients, six of whom were managed with artificial urinary sphincter. A delayed erosion developed in the proximal bulbous urethra of one patient, who had combined brachytherapy and external beam radiation, in spite of a transcorporeal placement. Two patients had complete wound separation and failure of fistula closure and subsequently underwent successful secondary reconstruction using the contralateral gracilis and semitendinosus muscle flaps.

ANTERIOR TRANSANOSPINCTERIC APPROACH

A small subset of eight patients who developed a post-traumatic posterior urethral distraction defect and a concomitant rectourethral fistula were managed by an anterior Gecelter transanosphincteric procedure with complementary addition of the gracilis muscle.²⁷ This technique was introduced by Gecelter in 1973 and is specifically used for small fistulas of traumatic or surgical origin when a simultaneous urethral reconstruction is planned and there is a normal anal sphincter without prior anorectal pathology. The approach affords wide access, ease of instrument maneuvering, facility to repair the proximal and posterior urethra and the ability to transfer buttressing interposition flaps, which consistently secure closure of the fistula in the non-radiated lesion. The technique is performed with the patient in the dorsolittotomy position using direct OR or yellow fin stirrups with the anus and rectum exposed. The fistula is catheterized cystoscopically using a ureteral catheter as a guide, and an anterior midsagittal incision is made extending from the scrotal base to the anal verge (Figure 61.6). The dissection is restricted to the midline where the transverse perineal muscles, central tendon, and anal sphincter complex are transected, inclusive of the internal and external components, and the rectal wall to the fistula site with further separation of the anterior rectal wall to the peritoneum with strict adherence to a midline dissection to prevent any anosphincter or cavernous nerve injury.

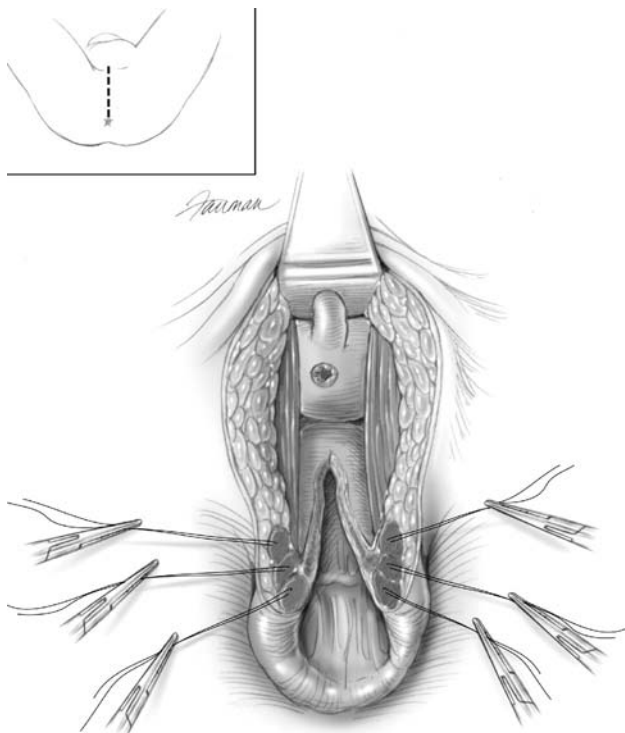


Figure 61.6 An anterior transanosphincteric midsagittal incision is performed through a midline anterior perineal route. The components of the external anal sphincter are tagged with 3-0 silk and the rectal wall separated from the urethra and subvisceral surface.

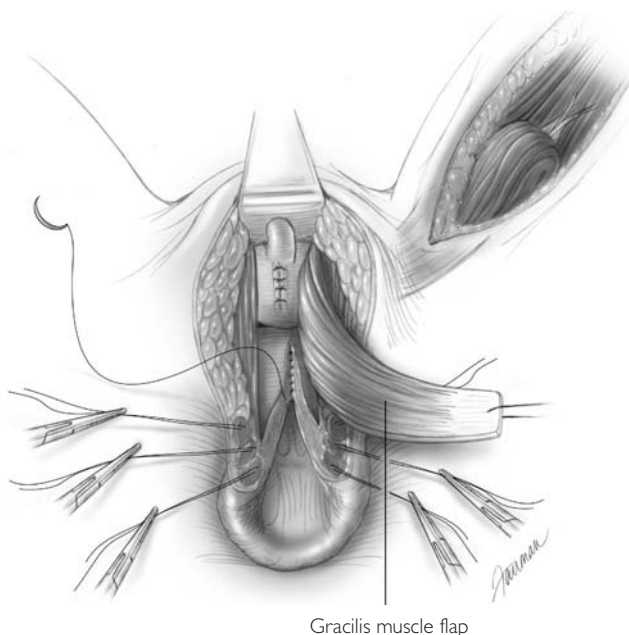


Figure 61.7 Following restoration of the rectal wall, internal and external sphincter anatomy, a gracilis muscle flap is interposed between the two suture lines.

The transverse perineal and external sphincter muscle segments are tagged in pairs with silk sutures for

subsequent anatomic restoration similar to the manner used in the York-Mason approach. Any urethral stricture can be managed at this point by either an anastomatic or a substitution urethroplasty followed by careful restoration of the rectal wall and anal sphincter. The rectum is closed by a two-layer 3-0 Vicryl interrupted technique and the internal and external anorectal musculature are approximated using the paired tagging sutures to help prevent the muscle from retracting (Figure 61.7).

The catheters are removed at 3–6 weeks if a voiding cystourethrogram demonstrates a secure closure. The fecal stoma is reversed in 3–6 months if repeat anal manometry and proctoscopy confirm an intact urethral and rectal wall. In general, anorectal sphincteric function will permit control of solid stool in 3–6 weeks and liquid and gas continence in 8–10 weeks after a trans-sphincteric closure.

CONCLUSION

A wide variety of surgical techniques have been introduced to manage rectourethral fistulas of numerous causes. Our experience dictates that the anterior perineal approach by a sphincter preserving or transanosphincter technique consistently offers a secure successful closure with preservation of rectal and urinary function in the properly selected cases. The basic tenets that must be adhered to are a careful and complete separation of rectum and urethra all the way to the peritoneum, an aggressive debridement of fibrous or necrotic tissue, a buccal mucosa patch graft for the urethral defect in the complex fistula, and the routine use of an interposition gracilis muscle flap to separate suture lines, enhance graft take, and bring an unimpaired circulation to this hypovascular space. This rectoconstructive approach should obviate the need for proctectomy in most complex large rectourethral fistulas of radiation origin, and consistently achieve successful closure in the fistula developing after radical prostatectomy.

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62 Cultured buccal mucosa grafts: current status

Jacob M Patterson, Sheila MacNeil, and Christopher R Chapple

INTRODUCTION

Substitution urethroplasty is the gold standard treatment for strictures or disruptions of the male urethra not amenable to excision and primary anastomotic repair, typically for strictures greater than 2 or 3 cm in length. Recently, buccal mucosa (BM) has been shown to be the ideal graft material,¹ especially for strictures involving the bulbar urethra. It is also especially useful for the treatment of strictures caused by balanitis xerotica obliterans (BXO, also known as lichen sclerosus [LS]), where BM appears to be more resistant to recurrent disease than genital skin.² Its use is extensively described in previous chapters.

In patients with extensive strictures and those who have undergone previous reconstructive surgery to the urethra, however, there is insufficient tissue available to harvest to completely treat the stricture. These patients have previously typically undergone combined graft and pedicled flap procedures, with extensive harvest of BM from the inner aspect of both cheeks and the inner lower lip. The use of bladder mucosa and colonic mucosa have both been reported but are associated with more morbidity. Even if BM alone is utilized, not surprisingly, the morbidity of graft harvest tends to be proportional to the length of tissue harvested,^{3–5} and indeed some patients are left with residual side-effects of BM harvest such as paraesthesia, pain, and reduced mouth opening, as well as flap donor-site morbidity.

We therefore set out to explore the possibility of developing a tissue-engineered buccal mucosa (TEBM) both to facilitate the surgery and in particular to reduce the morbidity to those patients undergoing substitution urethroplasty with extensive stricture burden.

METHODS

Ethical committee approval was granted for this study which encompassed both pre-clinical and clinical phases.

Preclinical work

Ideal culture conditions were defined. BM obtained from patients undergoing dental procedures and routine substitution urethroplasty was treated enzymatically to separate the epidermis from the dermis. Primary keratinocytes were obtained from the epidermis and subcultured (once) using Green's medium supplemented with 10% fetal calf serum (FCS) (10% Green's medium) to obtain an adequate number of cells; these cells were then either used fresh or maintained frozen for subsequent use. Fibroblasts were obtained from the dermis after collagenase treatment of finely minced dermis and subcultured at least four times (to passage 4) in Dulbecco's Modified Eagle's Medium (DMEM) supplemented with 10% FCS. It was necessary to subculture fibroblasts to four passages in order to obtain a pure culture and to yield adequate numbers to culture TEBM. Based on a skin model designed and used by the laboratory group for over 15 years for the investigation and treatment of postburns skin graft contraction, composite grafts were constructed by seeding both keratinocytes and fibroblasts onto de-epidermized human dermis (Figure 62.1). These composite grafts were cultured at an air–liquid interface for 10–28 days, and subjected to histologic and microbiologic examination. They were also tested for robustness and amenity to surgical manipulation by meshing and suturing around a catheter, to mimic the conditions they may be subjected to operatively. We have shown TEBM to be a robust tissue with no dermal–epidermal separation on meshing, and no abnormalities seen after extensive suturing, including contact with catheters. Histologically TEBM is near identical to native BM (Figure 62.2), and culture can easily be maintained in a sterile fashion. These findings have been reported by Bhargava et al.⁶

Clinical trial

After full informed consent we recruited five patients to our trial. All patients had strictures caused by BXO,

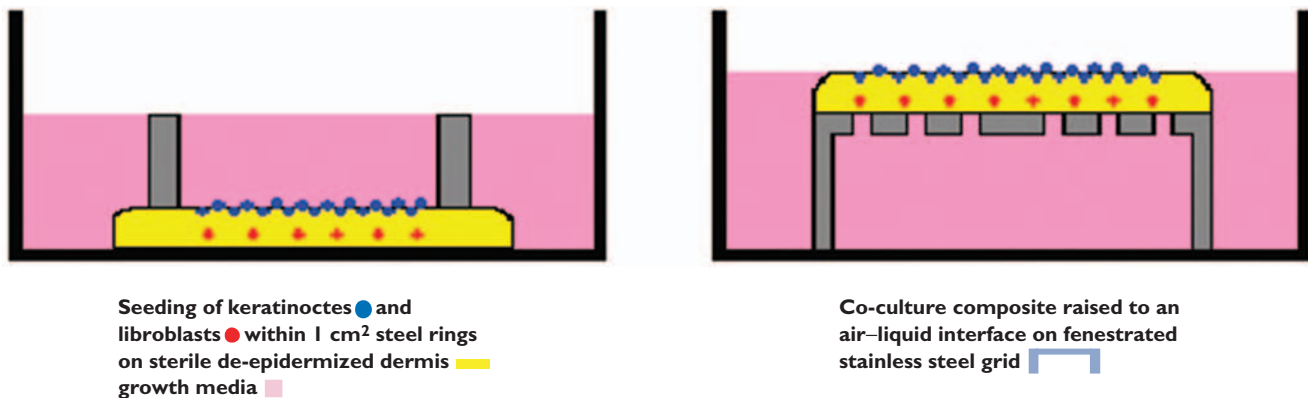


Figure 62.1 Co-culture of autologous oral keratinocytes and fibroblasts on sterilized de-epidermized human dermis. Reproduced with permission from the British Journal of Urology International. All rights reserved.

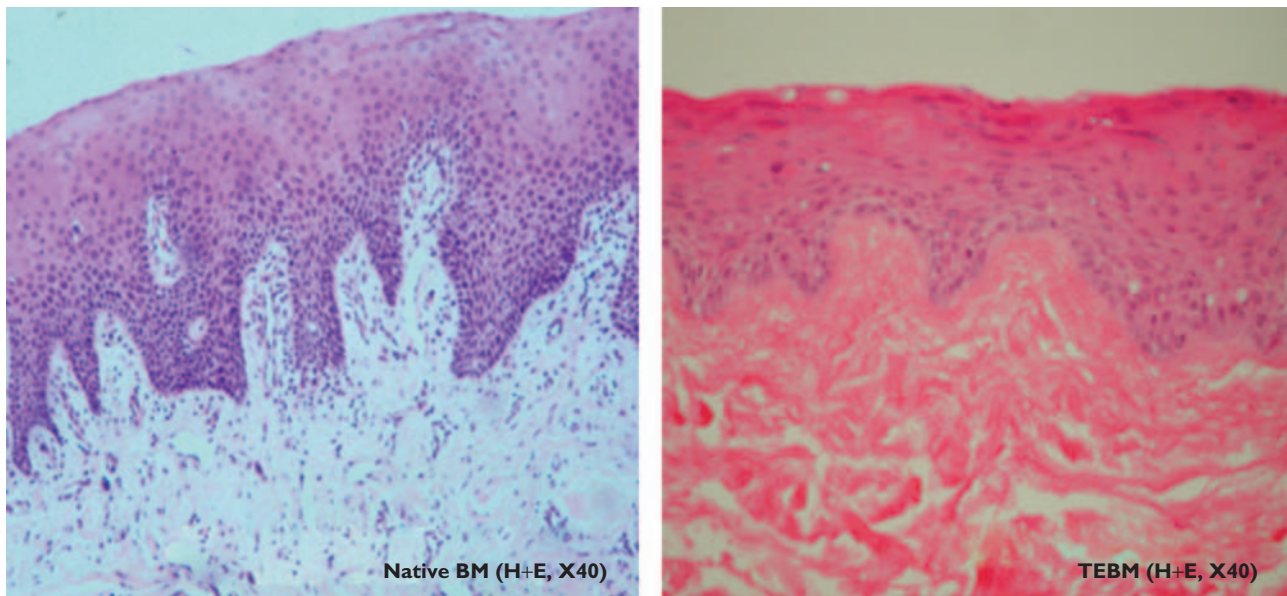


Figure 62.2 Histologic equivalence of native buccal mucosa (BM) and tissue-engineered buccal mucosa (TEBM). H+E, hematoxylin and eosin. Reproduced with permission from the British Journal of Urology International. All rights reserved.

affecting various sections of the anterior urethra. Four of the five patients involved had previously undergone at least one direct inline visual urethrotomy (DIVU), and three of these had also undergone at least one previous urethroplasty. The patient characteristics are summarized in Table 62.1.

BM biopsies of 0.5 × 0.5 cm were taken from each patient. These were processed in approved clean rooms to yield autologous oral keratinocytes and fibroblasts which were isolated and expanded in vitro. These were then seeded onto sterilized donor dermis in a 1:1 ratio, with 8.5×10^4 cells of each type per square centimeter of dermis; this was equivalent to 1.27×10^6 cells of each type per 3 × 5 cm graft. After a 7–10-day period of culture at air-liquid interface,

samples from each composite graft were sent for microbiologic and histologic assessment of sterility and suitability prior to implantation (Figure 62.3).

The patients were operated on by a single surgeon (CRC) between February and August 2004. Patients underwent one-stage or two-stage urethroplasty depending on site and extent of stricture, with the final decision being made at the time of surgery. All grafts were placed dorsally after incision or excision of the scarred urethra (Figure 62.4). The procedures are also summarized in Table 62.1. Irrespective of the surgery performed, all patients had both urethral and suprapubic catheters inserted intraoperatively. They received 5 days of intravenous antibiotics and were observed in hospital to ensure there was no evidence

Table 62.1 Characteristics of patients

Patient	Age (years)	Stricture site	Previous surgery	Planned procedure
1-PS	43	Meatus-verumontanum	DIVU x2 Penile skin urethroplasty 1995	Redo two-stage urethroplasty with BM, insufficient tissue therefore distal first-stage completed with TEBM
2-JA	46	Penile urethra	DIVU 2002	Two-stage TEBM urethroplasty
3-RA	56	Penoscrotal junction-distal sphincter mechanism	DIVU 1987 Urethroplasty 1987	Single-stage dorsal onlay TEBM urethroplasty
4-ST	44	Bulbar urethra	Nil	Single-stage dorsal onlay TEBM urethroplasty
5-DM	27	Penile urethra (glanular urethra excepted)	Buccal mucosa urethroplasty x2	Redo two-stage urethroplasty with TEBM

DIVU, direct inline visual urethrotomy; BM, buccal mucosa; TEBM, tissue-engineered buccal mucosa.

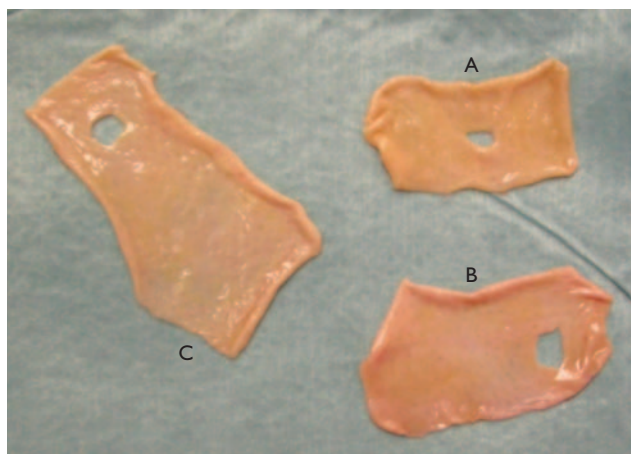


Figure 62.3 TEBM prepared prior to clinical use; small segment removed for microbiologic and histologic assessment.

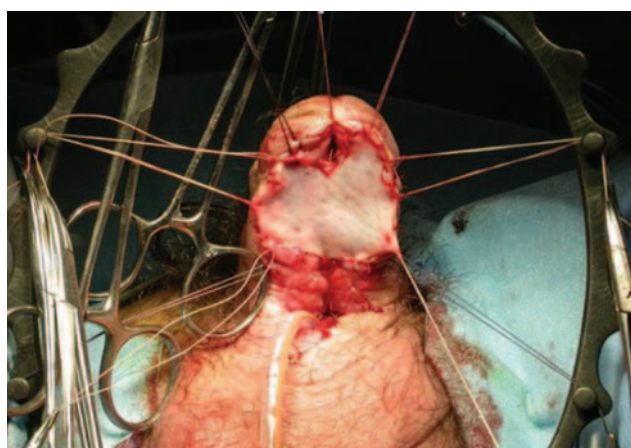


Figure 62.4 TEBM used to complete distal first-stage urethroplasty.

of graft loss. Retrograde and voiding urethrography was performed before removal of the urethral catheter to ensure patency and to check for leakage or extravasation of contrast. This was carried out after 14 days in one-stage procedures and after 10 days following the second stage of two-stage procedures. In two-stage procedures, the urethral catheter was removed after 10 days, and with established voiding (from perineal urethrostomy or proximal penile urethrostomy) the patients were discharged home. All patients were reviewed at 6 weeks, 3 months, and 6 months, and when considered suitable for a second-stage repair, this was subsequently carried out at 6–9 months after the first stage. All patients, including those who underwent a second stage were reviewed according to the same timescale, and subsequently at 6-month periods. Follow-up included flexible urethrocystoscopy (Figures 62.5 and 62.6) where the urethra had been closed in preference to a combination of radiologic investigation and measurement of urine flow rates; early recurrence can be missed on flow rate examination, as substantial luminal loss to less than 11 Fr has to occur before flow rate is appreciably affected. Also, the appearance of the urethra after urethroplasty is often abnormal and tortuous, and early recurrences could easily be missed as a result. The above is standard follow-up practice for all patients undergoing urethroplasty in our unit.

RESULTS

To date we have medium-term follow-up for our cohort, of between 12 and 30 months. The first patient

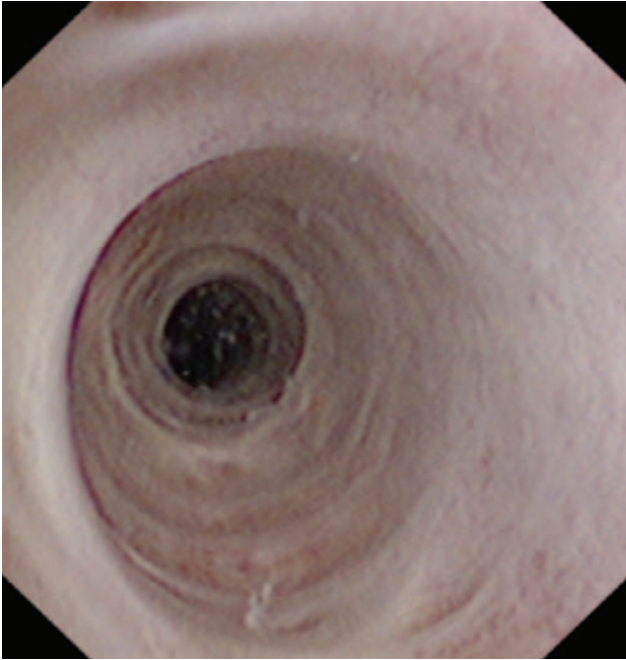


Figure 62.5 Urethroscopic appearance of TEBM graft in situ in bulbar urethra after one-stage dorsal onlay graft.

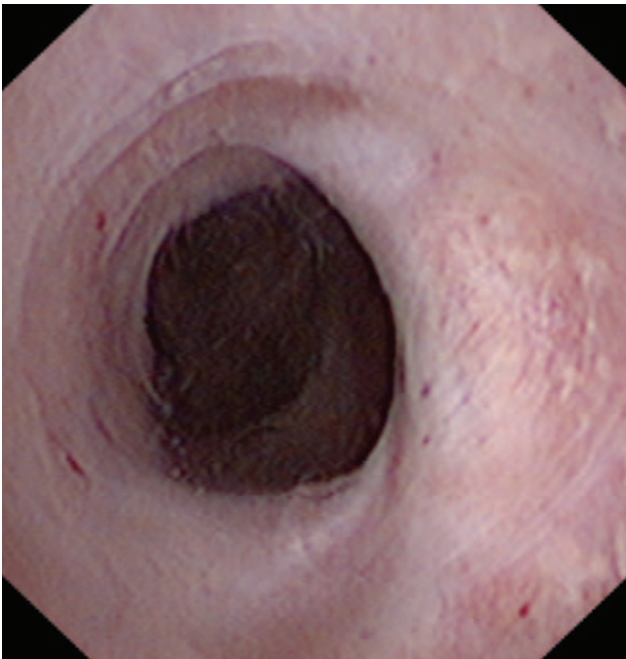


Figure 62.6 Urethroscopic appearance of TEBM graft in situ in penile urethra after two-stage dorsal onlay graft.

underwent a combination procedure using both native BM and TEBM, with the TEBM applied distally (Figure 62.4). The second stage was carried out after 6 months when the graft had taken well, with no signs of rejection, ischemia, or excessive scarring. At 30-month



Figure 62.7 Exudative response to TEBM graft.

follow-up, we have no evidence of recurrence of stricture, although the patient does have a degree of sub-meatal stenosis which is asymptomatic, and managed with intermittent self meatal dilatation. Our second patient developed severe fibrosis and scarring with associated mucosal hyperproliferation 6 weeks after first-stage of a planned two-stage procedure. This necessitated complete excision of that area of the graft and revision with native buccal mucosa, which was carried out without complication after 6 months. It was also noticed that initially there was a marked exudative response to the graft (Figure 62.7), which is not typically seen with autologous BM grafts applied in this manner. Both the third and fourth patients underwent single-stage dorsal onlay bulbar urethroplasty, with both patients receiving 9×3 cm grafts. Initially, after removal of the catheter, and at all initial follow-up visits there was no recurrence of stricture in either patient, but at 7 months in one and 11 months in the other, recurrent stricture was noted on urethroscopy. Neither patient had complained of a subjective deterioration in flow. Both recurrences were in the region of the distal anastomosis, and were diaphragmatic in nature. The patients underwent DIVU and then performed intermittent self dilatation of the urethra twice weekly. Neither had evidence of further recurrence at 28 months after urethroplasty. The fifth patient had a two-stage procedure. Again, a markedly exudative response to the graft was noted and after 3 months, it was noted that the proximal segment of the graft had become hyperproliferative and scarred. There was also an associated chordee. In view of this, the proximal 4.5 cm was revised with native BM after 6 months, and after 9 further months, the urethra was closed. A urethrocuteaneous fistula which was evident in the postoperative period settled spontaneously with no need for

Table 62.2 Patient outcomes

Patient	Procedure	Short-term outcome	Medium-term outcome
1-PS	Redo two-stage urethroplasty with BM, TEBM distal graft only	No graft failure/rejection Symptomatically normal	Asymptomatic submeatal stenosis, managed with intermittent meatal dilatation No further recurrence
2-JA	Two-stage TEBM urethroplasty	No graft failure/rejection After 5 months significant fibrosis of graft and penile shaft necessitating complete revision	Second stage completed successfully after first stage revised with native BM. No recurrence at 11 months
3-RA	Single-stage dorsal onlay TEBM urethroplasty	Uneventful recovery from single-stage procedure	Slight stenosis (asymptomatic) in area of distal anastomosis at 11 months, treated with DIVU and managed with intermittent self dilatation No further recurrence
4-ST	Single-stage dorsal onlay TEBM urethroplasty	Uneventful recovery from single-stage procedure	Slight stenosis (asymptomatic) in area of distal anastomosis at 7 months, treated with DIVU and managed with intermittent self dilatation No further recurrence
5-DM	Redo two-stage urethroplasty with TEBM	No graft failure/rejection At 6 months, proximal graft hyperproliferative and scarred (++), therefore proximal 4.5 cm revised with native BM	Second stage completed successfully, small urethrocuteaneous fistula settled without intervention Good caliber urethra with no recurrence to date

DIVU, direct inline visual urethrotomy; BM, buccal mucosa; TEBM, tissue-engineered buccal mucosa.

further surgical intervention. At follow-up to 8 months after second stage, there was no evidence of recurrent stricture. The results are also summarized in Table 62.2.

DISCUSSION

Before considering the results in detail it is important to consider the nature of the patient population under treatment. The patients treated in this series all had BXO, with the characteristic severe associated urethral and periurethral fibrosis. The rationale for selecting these patients was to have a number of two-stage procedures to allow inspection of the graft on the penile urethra, prior to the second-stage procedure. This is the first report of the use of tissue engineered oral mucosa for substitution urethroplasty and it is important to look at all aspects of the procedure to identify problems and seek improvements.

All the grafts took well, with no sign of rejection or ischemia in the initial postoperative period, and the operations themselves were without significant complication. However, in two cases we encountered significant fibrosis of the graft necessitating partial or

complete excision of the TEBM. In these patients a prolific exudative response was also seen which is atypical of our normal practice of BM urethroplasty. Also, although recurrence of stricture in the region of anastomoses is recognized,⁷ this was more common in this small series than is our usual experience. Essentially, the complications we have encountered can be summarized as being caused by graft contraction or fibrosis. We are unsure as to the exact etiology of these problems, but they could be caused by one or a combination of the following.

- (1) Higher rate of graft failure and recurrent stricture in patients with extensive disease due to BXO. All of our patients had strictures caused by BXO, and this could be the predominant reason that we encountered such a high complication rate.
- (2) Delayed vascularization of the TEBM compared with native BM. BM has a rich capillary network which is absent in our tissue engineered composite grafts. However, as the grafts are cultured at air-liquid interface, they are shown to be able to imbibe nutrients from their under surface; in this case the corpora cavernosa.

- (3) Reaction to allodermis or xenobiotic proteins. All cells and composites are cultured in media containing bovine serum, which could theoretically provoke an immune response. The donor dermis, although sterilized and acellular, may have residual basement membrane proteins which could have a similar effect.
- (4) Contraction of the graft after being sutured into place. Native BM has a recognized attrition rate, and the composite grafts have been shown to contract in vitro due to the mechanical effects on the dermis exerted by the keratinocytes and fibroblasts.⁸
- (5) Recurrent narrowing of the urethral lumen which might not have had clinical significance but was detected on urethroscopic surveillance. (However, by treating recurrence early we demonstrated good outcomes with which the patients were happy.)

We have had reasonable outcomes in all our patients except for one, and in none have symptomatic strictures recurred. Despite this, two patients have required surgical intervention to treat recurrent stricture (DIVU) and three performed some form of regular urethral instrumentation to maintain patency. However, we have achieved one of our principal objectives, in that no patient had any side-effects from giving an oral biopsy, and there were no side-effects from BM harvest at the time of their urethroplasty.

FUTURE WORK

The current study is valuable in showing the potential and identifying the problems in using tissue engineered oral mucosa for substitution urethroplasty. Our current pre-clinical work is directed towards a better understanding of the processes involved in contraction and fibrosis of the grafts. We use a scaled-down model of the composite graft to study contraction over time and observe the effects of adding variables to the culture process to assess their effect in vitro.⁹ To date, we have several possible therapeutic targets, including pharmacotherapy to affect collagen cross-linking, pretreatment of the donor dermis to make it resistant to contraction, and the use of synthetic scaffolds which are resistant to contraction as

well as being bioabsorbable and biocompatible. In addition we are trying to remove all xenobiotic materials from the culture process to reduce the possible complications of excess immune reactivity as well as the potential risk of viral or prion disease transmission to the patient.

CONCLUSIONS

TEBM for substitution urethroplasty is a potentially viable alternative to using patients' own buccal mucosa, especially in cases where extensive strictures need treating or where multiple previous procedures have been carried out and there is a paucity of available tissue for grafting. We have successfully shown a reduction in morbidity to the patients undergoing substitution urethroplasty with respect to the harvest of BM, and have shown a reliable and reproducible culture method for manufacturing TEBM. However, the results of ongoing work are awaited where we are attempting to reduce the contraction and fibrosis of the graft and also avoid the use of any xenobiotic materials in the production of the graft to increase the safety to the patient, before the use of TEBM can be introduced into routine clinical practice.

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63 Acellular matrix: current status

Abdel W El-Kassaby

Replacement of damaged or diseased tissues has been one of the most challenging aspects in medicine. Tissue replacement within the urinary tract is a technically demanding procedure, particularly urethral reconstruction which has posed a continuing challenge to the reconstructive urologist. Various techniques utilizing flaps or grafts (genital/extragenital), whether single or multistage, have been used in the armamentarium of urethral reconstruction with satisfactory results. However, in complex and recurrent cases, enough non-hirsute genital skin is not always available in amount and quality. Although different types of grafts have been employed including split-thickness and full-thickness skin, bladder mucosa, and buccal mucosa grafts (which have become the favored graft for urethral substitution),¹ yet they may not always be sufficient to bridge long defects.

The need for skillful and experienced surgeons; elimination of donor site morbidity;² shorter operative duration; and decreased blood loss, pain, scarring, numbness at the harvest site, and potential cosmetic deformity, all make the use of 'off-the-shelf' graft tissue a dream for urethroplasticians. The advent of 'tissue engineering' could provide this off-the-shelf ready to employ graft tissue of unrestricted dimensions and allow the patient's own native urethra to regenerate with reconstitution of the normal urethral wall.

Creation of biologic substitutes is the function of the science of tissue engineering. Tissue engineering is defined as the interdisciplinary field which applies the principles of engineering and life sciences toward the development of biologic substitutes that aim to maintain, restore, or improve tissue function.³ The term 'regenerative medicine' involves the diverse areas of tissue engineering, stem cells, and cloning, towards the common goals of developing biologic substitutes which would restore and maintain normal tissue and organ function.⁴ Originally, the concept of engineering tissue using selective cell transplantation was applied clinically for a variety of disorders, including the use of engineered skin for burn patients.⁵ In tissue engineering, the implanted tissue can be either heterologous, allogeneic, or autologous.⁶ Tissue engineering could be used to develop biologic substitutes in one of three forms: cultured cells alone, acellular matrix alone, or cellular (cell-seeded) matrix.

The implantable matrices or scaffolds act to direct new tissue growth which depends on the body's inherent ability to regenerate,⁴ i.e. scaffolds guide tissue growth in a pre-determined pattern. Also, scaffolds provide structural support upon which cells can grow and establish their needed blood supply.⁷ The matrix or scaffold allows cell survival by diffusion of nutrients across short distances, then the matrix becomes vascularized in concert with expansion of the cell mass after implantation.⁶ This process of vascularization allows effective repair and regeneration of injured tissues which depend on early re-establishment of the blood flow needed for cellular infiltration and metabolic requirements. Ideally, the scaffold should serve as an extracellular matrix (ECM) in which cell behavior can be regulated to develop tissue structure. The ultimate biomaterial should therefore promote cell adhesion, proliferation, migration, and differentiation, be biocompatible and biodegradable, and have appropriate mechanical and physical properties.⁸

Scaffolds can facilitate the delivery of bioactive factors (e.g. cell adhesion peptides, growth factors, etc.) to desired sites in the body.⁹ Scaffolds could be synthetic (artificial) polymers or biologic (natural) polymers. Biologic (natural) polymers include acellular tissue matrices (e.g. bladder submucosa and small intestinal submucosa).⁴

SYNTHETIC SCAFFOLDS

Synthetically derived scaffolds serve as backbones for tissue repair and regeneration. These synthetic polymer scaffolds are strong, can be fabricated to degrade following implantation at predetermined rates, and can be designed to mimic the material properties of the native tissue they are designed to replace. While these characteristics are appealing, several clinical complications are often encountered. Although many synthetic biopolymers have been used to replace damaged vascular structures, and while long-term patency rates have risen over the years, the ideal vascular graft scaffold remains elusive. For example, no synthetic biopolymer, currently available for clinical use, can restore normal structure and function to injured vascular tissues while avoiding

severe complications such as thrombosis, neointimal hyperplasia, accelerated atherosclerosis, and/or calcification.^{10,11} Many synthetic biopolymers, such as hyaluronic acid based polymers, support the growth of cells in dedifferentiated or incompletely redifferentiated states¹² or, like polyglycolic acid (PGA), lead to tissue deposition that is less than optimal.¹³ Synthetic scaffolds should be made of biodegradable polymers as permanent synthetic biopolymers, e.g. silicone and polytetrafluoroethylene (PTFE), carry the risk of infection, calcification, and the formation of excessive scar tissue.^{14–16} Efforts for urethral replacement with synthetic scaffold have been associated with poor results.^{17,18} Also, in the urinary bladder, artificial biodegradable scaffolds contract with time and lead to diminished bladder capacities.⁶ So, developing biologic substitutes has been explored.

BIOLOGIC (NATURAL) POLYMERS

Another approach to the repair and regeneration of damaged tissues is the use of intact ECM obtained from animal tissues to act as the growth support for host cells.

Native biologic tissue is formed of two basic components: cells and ECM. ECM refers to any material part of a tissue that is not part of any cell, i.e. it is the non-cellular part of a tissue that provides support to cells and controls the structure of the tissue and regulates the cell phenotype.¹⁹ ECM consists of protein and carbohydrate structures secreted by the resident cells. The most common constituent of the ECM is the structural protein, collagen. When harvested from the tissue source and fabricated into graft prosthesis, by removing the cells and subjecting the ECM to mechanical and chemical processing, these ECM materials may be referred to as naturally occurring polymeric scaffolds, bioscaffolds, or biomatrices. These materials, though harvested from several different body systems, all share similarities when processed into a graft material. Specifically, since they are subjected to minimal processing after they are removed from the source animal, they retain a structure and composition nearly identical to their native state. The host cells are removed and the scaffolds are implanted acellularly to replace diseased or damaged tissues. These naturally occurring materials offer promising alternatives to synthetically engineered polymeric scaffolds for tissue repair and regeneration.

Naturally occurring scaffolds can be processed in such a way as to retain growth factors, such as basic

fibroblast growth factor (FGF-2) and transforming growth factor- β (TGF- β),^{20,21} glycosaminoglycans, such as heparin and dermatan sulfate,^{22–24} and structural elements, such as fibronectin,²⁵ elastin, and collagen.²⁶ These materials prevent many of the complications associated with foreign material implants because they provide a natural environment onto which cells can attach and migrate, then they can proliferate and differentiate. These naturally occurring biopolymers have been shown to interact quickly with the host's tissues, induce the deposition of cells and additional ECM, and promote rapid angiogenesis, all of which are essential to the restoration of functional soft tissue.

Naturally occurring biopolymers include small intestinal submucosa (SIS), acellular dermis, cadaveric fascia, bladder acellular matrix graft (BAMG), and amniotic membrane.

SMALL INTESTINAL SUBMUCOSA

SIS is an acellular matrix that consists of three distinct layers of the mammalian small intestine: lamina propria, muscularis mucosae, and tunica submucosa.²⁷ The tunica submucosa is the layer of connective tissue arranged immediately under the mucosa layer of the intestine and is a 100–200 μ m thick interstitial ECM; it makes up the bulk of the SIS biopolymer scaffold. In the living intestine, the submucosa supports the mucosal structures and is secreted and maintained by the fibroblasts which reside there.²⁸ SIS is comprised primarily of fibrillar collagens, and adhesive glycoproteins,²⁵ which serve as a scaffold into which cells can migrate and multiply. The SIS layers also contain potent regulatory factors, such as glycosaminoglycans, proteoglycans, and growth factors, which regulate cellular processes that maintain tissue homeostasis and respond to injury and infection.²⁸ Many of these components are retained in the biopolymer scaffold following processing. SIS is harvested from the mammalian small intestine by mechanically separating it from its outer muscular layers and internal mucosal layers. The biopolymer is thoroughly rinsed in water, treated with an aqueous solution of 0.1% peracetic acid, and rinsed in sequential exchanges of water and phosphate buffered saline to yield a neutral pH.²⁹ It is then either stored in an antibiotic solution containing 0.05% gentamicin sulfate,³⁰ or sterilized using 2.5 mRad gamma irradiation.²⁹

When SIS is implanted as a naturally occurring biopolymer scaffold, it stimulates angiogenesis and connective and epithelial tissue growth and differentiation,

as well as deposition, organization, and maturation of ECM components that are functionally and histologically appropriate to the site of implantation.²⁷ When used as a graft material for bladder augmentation in dogs, the reconstructed tissue from SIS is structurally and functionally similar to native bladder tissue. However, the muscle layer is not fully developed, and a large amount of collagen is interspersed among fewer muscle bundles.³¹ SIS has also been used experimentally for urethral augmentation.^{32–35} Kropp et al³² used SIS as an onlay patch in urethroplasty in rabbits. In this experiment SIS promoted regeneration of three to four layers of stratified columnar epithelium as well as suburothelial circular smooth muscles. El-Assamy et al³⁵ evaluated the use of single-layer SIS for urethral replacement in a rabbit model, as both an onlay and a tube graft compared with control groups for spontaneous urethral regeneration. All rabbits developed urethral strictures with progressive narrowing when applying SIS as a tube graft. Six out of nine rabbits with onlay patch graft had normal urethrograms, while there was relative narrowing in the other three. However, histologic examination showed epithelial regeneration with no regeneration of smooth muscle in the region of SIS onlay graft at up to 3 months; instead fibrous connective tissue was present. Healing was inferior to spontaneously healed non-patched urethrae which showed regeneration of bundles of smooth muscle circumferentially surrounding the urethral mucosa.

In humans, Mantovani et al³⁶ published a series of five patients in whom SIS was used in urethral stricture repair. Their patients had no recurrences at 6 months after surgery. However, Hauser et al³⁷ used SIS as a dorsal onlay patch urethroplasty in five patients. Recurrent urethral stricture developed in four patients after a median of 14 months. Also, SIS has been used in the management of ureteral strictures in experimental animal studies. All three layers of the native ureter (urothelium, smooth muscle, and adventitia) had replaced the SIS graft without evidence of significant obstruction.^{38,39} O'Connor et al⁴⁰ reported the first human use of tubularized SIS to replace a 5 cm strictured segment of distal ureter in a single case. Although histologic analysis was not available, ureteroscopy at 12 weeks showed total incorporation of the submucosal graft into the native tissue with 15-month follow-up. SIS has been used for corporal body grafting, in correcting severe chordee and complicated hypospadias, and in the surgical management of Peyronie's disease with a success rate of 80% in the short term.^{41–43}

Acellular dermal matrix

Skin is comprised of two primary layers that differ in function, thickness, and strength: the epidermis and the dermis. The dermis underlies the epidermis and possesses an extensive vascular system that supplies the epidermis with nutrient-rich blood and helps the skin regulate temperature. The dermis is composed of fibroblasts, which produce a collagen-containing ECM that provides elasticity and support to the skin.

Acellular dermis is harvested from either pig skin or human cadaver skin. The epidermis is removed by soaking the skin in 1 mol/l NaCl for 8 hours. Dermal fibroblasts and epithelial cells are removed by incubation of the material in 2% deoxycholic acid containing 10 mmol/l ethylenediaminetetraacetate (EDTA). The dermis is then cryoprotected with a combination of 35% maltodextrin and 10 mmol/l disodium-EDTA, and freeze dried until use.²⁶ When implanted as an acellular tissue graft, acellular dermis supported endothelialization of repaired vascular structures,⁴⁴ inhibited excessive wound contraction,⁴⁵ and supported host cell incorporation and capillary ingrowth into the grafted site.^{46,47} By using acellular de-epidermized dermis (DED), Bhargava et al¹ reported the successful culture of tissue-engineered buccal mucosa (TEBM) that closely resembled the native oral mucosa and was suitable for use in substitution urethroplasty. The preparation and clinical use of TEBM are discussed in more detail in a separate chapter.

Cadaveric fascia lata

The tensor fascia lata is the thick band of connective tissue attaching the pelvis to the knee on the lateral side of the leg. Its muscular components at the hip join to form thick connective tissues that help stabilize and steady the hip and knee joints by putting tension on the iliotibial band (IT band). The IT band, and the distal section of the tensor fascia lata, is harvested for the graft prosthesis. In its native state, the fascia lata tendon is composed of heavy, parallel bundles of type I collagenous fibers that are held together by ECM tissue. Between the bundles of fibers are fibroblasts, nerves, and blood vessels that supply the tendon with nutrients.

Processing of cadaveric fascia involves ethanol extraction followed by high-pressure washing with antibiotics. The extracted tissue is then lyophilized and terminally sterilized with gamma irradiation. Intraoperatively, the grafts are reconstituted in a 0.9%

saline soak for 30 minutes prior to implantation.⁴⁸ Evaluation of the graft material revealed an almost pure collagen tissue structure.⁴⁹ Fascia lata is characterized by collagen and elastic fibers running longitudinally, and with interspersed fibroblasts aligned with those fibers. One of the popular uses of fascia lata is in female stress urinary incontinence and genitourinary prolapse. Although not completely acellular, the relative paucity of cells is probably the major characteristic that allows the successful use of donor fascia without matching of donor and recipient.⁵⁰ Furthermore, one study using fresh-frozen donor fascia lata allografts in rabbit cornea showed that after 1 week, donor fascia lata fibroblasts were absent. Within 3 weeks, the grafts were repopulated by host fibroblasts.⁵¹

Amniotic membrane

The amniotic membrane forms the sac that encloses the embryo during pregnancy. It is an extremely strong, 5–20 μm thick tissue that has been used as a graft in several tissue repair applications. In its native state, the epithelium of the amnion consists of a single layer of cells resting upon a relatively cell-free basement membrane ECM.⁵² This ECM is comprised of several collagen types, including the fibrillar collagen types I and III, and the basal lamina collagen type IV.^{52,53} Several growth factors, including epidermal growth factor, several transforming growth factor isoforms, basic fibroblast growth factor, keratinocyte growth factor, and hepatocyte growth factor also have been recently identified and have been reported to be retained in the processed tissue matrix.²⁰

Amniotic membrane is obtained at parturition and cleaned of blood with saline containing penicillin, streptomycin, amphotericin B, and clindamycin.⁵⁴ It is separated from the chorion by blunt dissection, washed in sterile water, and treated by soaking for 3 hours in a 10% solution of trypsin to lyse the cells. The membrane is then sterilized with gamma irradiation and frozen until clinical use.^{55,56}

Bladder acellular matrix graft

BAMG was first described in 1975.⁵⁷ BAMG is a collagen-based matrix, derived from allogenic bladder submucosa that is analogous to the submucosal tissue comprising the bulk of the SIS biomaterial. Unlike the intestinal submucosa, however, which is easily separated from the external muscle layers, the submucosa

of the urinary bladder is intimately attached to the muscular bladder wall. Complete mechanical separation of the layers has proven tedious and difficult, and so attempts at rendering the bladder submucosa muscle free have often resorted to chemical and/or enzymatic agents such as sodium hydroxide, sodium desoxycholate, sodium dodecyl sulfate (SDS), or deoxyribonuclease.^{29,58–60} In one processing method, whole bladders were soaked in a Tris-EDTA solution for 48 hours followed by additional soaking in Tris-potassium chloride-EDTA solution containing Triton-X. Bladders were then rinsed in Sorenson's phosphate buffer solution, incubated overnight with deoxyribonuclease and ribonuclease to remove cytoplasmic and nuclear material, and further extracted in a solution containing Tris and SDS. The extracted bladders were then submerged in 70% ethanol for 24 hours to remove any residual SDS, washed in phosphate buffer, and stored in refrigerated saline until use.³³ Alternatively, bladder submucosa was rendered acellular and sterile according to the methods used for SIS.²⁹ The bladder layers were mechanically separated and the resulting submucosa was thoroughly rinsed in water to lyse the cells. The submucosa was treated for 2 hours with 0.1% peracetic acid and then rinsed in sequential exchanges of water and phosphate buffered saline to yield a neutral pH. It was then sterilized using 2.5 mRad gamma irradiation and stored refrigerated until use.

When implanted as a replacement for bladder tissue, BAMG acted as the stimulus for whole bladder regeneration and restoration of bladder function.⁶⁰ It incited the restoration of a urothelium complete with newly formed ECM, underlying smooth muscle cells, and immature blood vessels, indicative of a neovascular response.⁵⁹ Its effects mirrored those observed when SIS was used for bladder augmentation.^{61,62}

Structurally, the BAMG was determined to be composed primarily of type I and type III collagen and elastin,^{58,63} but also contained other ECM components, including fibronectin, glycosaminoglycans (Hodde, unpublished data), and several growth factors.²⁹ Depending on the method of decellularization, the retention of matrix components other than collagen and elastin has been variable. Specifically, the decellularization method used by Reddy et al⁵⁹ retained only 25% of the protein matter of the native bladder, all of which was elastin and collagen, whereas the method used by Badylak et al²⁹ also retained glycosaminoglycans, glycoproteins, and growth factors.

The evaluation of the BAMG for tissue repair has largely been limited to urologic applications, though

Bedlam et al reported the evaluation of BAMG for the repair of segmental esophageal defects.²⁹ In the urinary system, the most common investigative use has been in augmentation cytoplasty and urethral reconstruction. Probst et al used BAMG for bladder augmentation in dogs and confirmed that the reconstructed bladder matched the morphologic and functional properties of the normal bladder.⁶³ Also, in a rat model, there was regeneration of all cellular components of the bladder.^{64,65} However, Sutherland et al⁶⁶ reported that the muscle layer, although present, was not fully developed. Oberpenning et al⁶⁷ compared the outcome of acellular matrix with cell-seeded matrix for augmentation cystoplasty in an animal model after subtotal cystectomy. Autologous urothelial and smooth muscle cells seed the latter. The acellular matrix graft tissue-engineered bladders maintained average capacities of 46% of the initial values compared with 95% in cell-seeded matrix tissue-engineered bladders. These findings were confirmed radiographically. Also, a marked decrease in bladder compliance (42%) was measured in the acellular matrix group compared with normal compliance in cell-seeded matrix tissue-engineered bladders. Histologically, the polymer-only bladders had a pattern of normal urothelial cells with a thickened fibrotic submucosa, and a thin layer of muscle fibers. The cell-seeded matrix tissue-engineered bladders had a normal cellular organization, consisting of a triple-layer of urothelium, submucosa, and muscle. Obara et al⁶⁸ assessed the feasibility of bladder acellular matrix (BAM) grafting onto the bladder of rats with spinal cord injury (SCI). Regenerated urothelium, smooth muscles, and nerve fibers in the grafted BAM appeared at 2, 4, and 12 weeks, respectively, in both intact and SCI rats. Immunohistologic examination showed that these regenerated tissues inherited each characteristic of the host bladder tissue and the grafted BAM showed proper distention to store urine at 12 weeks. Atala et al⁶⁹ employed tissue-engineered autologous bladders clinically for cystoplasty in seven patients with myelomeningocele and end-stage bladder disease. Autologous urothelial and muscle cells were seeded on a biodegradable bladder-shaped scaffold made of collagen, or a composite of collagen and polyglycolic acid. The autologous-engineered bladder constructs were implanted either with or without an omental wrap. After a mean follow-up of 46 months, the mean volume and compliance increased by up to 2.8 fold.

Various acellular scaffolds have been used experimentally in animal models for the regeneration of urethral tissue.⁷⁰⁻⁷² In animal studies, segments of the urethra were resected and replaced with BAMG in an onlay

fashion. Histologic examination showed complete epithelialization and progressive vessel and muscle infiltration, and the animals were able to void through the neourethras with no signs of strictures or complications.⁷¹ Sievert et al⁷² showed, in a rabbit model, that all tissue components were seen in the grafted matrix after 3 months. The smooth muscle in the matrix was, however, less than in the normal rabbit urethra.

The results of these experimental works paved the way for application of acellular matrices clinically. Atala et al⁷³ reported on the uses of homologous BAMG in treatment of urethral pathology in humans. They applied BAMG in a series of patients with history of failed hypospadias reconstruction, in which the urethral defects were repaired with an onlay patch. Three out of the four patients had successful outcome. Consequent to the above report, El-Kassaby et al⁷⁴ applied the same material clinically in the treatment of urethral stricture disease. Stricture length ranged between 1.5 and 16 cm. Our results were quite satisfactory as 24 of our 28 patients had a successful outcome after a mean follow-up of 37 months. This high success rate could be explained by the careful selection of patients, as this was not a randomized study. Furthermore, BAMG was employed as onlay patch in five children with urethral stricture and insufficient skin. We reported successful outcome in four of them after a mean of 30 months of follow-up.⁷⁵

These acellular collagen matrices were applied as an onlay patch on the 'ventral' aspect of the urethra. We believe that the use of acellular scaffold graft as 'dorsal' onlay patch graft as reported by Hauser et al³⁷ is neither necessary nor helpful in urethral stricture disease. The dorsally incised urethra could be fixed widely apart to the tunica albuginea covering the under surface of the corpora and the urethral mucosa will regenerate on the roof with or without acellular scaffold based upon Monseur technique.⁷⁶ In a dog model, Shokeir et al⁷⁷ reported the use of urethral acellular matrix (organ-specific) and applied it as a ventral onlay patch. They compared regeneration over the acellular matrix (study group) versus without matrix (control group). Histopathologic examination showed gradual regeneration over the acellular matrix with normal appearance at 20 weeks. In the control group, normal healing was observed at 2 months and thereafter. They concluded that regeneration of all components of the urethra could occur with or without acellular matrix. This is attributed to the fact that they were dealing with normal urethra that is capable of spontaneous regeneration. In essence, this follows the principles of Russell's technique⁷⁸ and Denis-Browne

buried skin strip that necessitates a healthy strip to regenerate into a tube over a splinting catheter.

This ensures the importance of verifying the presence of rather healthy urethral edges, after stricturotomy, that are capable of regeneration before adopting acellular graft onlay patch, so as to optimize subsequent regenerative process. If the strip were unhealthy, the outcome would be poor. In those patients excision of most of the fibrotic segment and roof strip anastomosis of the urethra is performed according to Russell technique.⁷⁸ This will decrease the length of the required patch graft and, more importantly, will guarantee to have rather healthy urethral edges that are capable of regeneration, as illustrated in cases 2 and 4 below.

A prospective randomized comparative study between buccal mucosa and BAMG grafts in management of urethral stricture disease has been conducted by the author and his group (El Kassaby et al, unpublished data). The study included 30 patients having an anterior urethral stricture with lack of native autologous tissue available for repair. Patients were randomly divided between buccal mucosa graft and BAMG repairs. The patients' ages ranged from 21 to 59 years (average 36.2), the length of the stricture ranged from 2 to 18 cm (average 6.9 cm). Eleven patients had purely bulbar strictures, seven had purely pendulous strictures, and 12 had combined bulbopendulous strictures. The graft was obtained either off-the-shelf (BAMG) or from the oral cavity through the regular harvesting technique of buccal mucosa. The graft was then tailored to the required length and width of the stricture and was applied on the floor of the urethra in an onlay fashion. Surgical outcome was successful in all buccal mucosal patients with a success rate of 100%. In the BAMG group of patients, success rate varied according to the number of previous surgical operations. From the nine patients with fewer than two previous operations, eight had a successful outcome while one patient had to undergo end-to-end anastomosis for a recurrent stricture. In the other group of BAMG (with two or more previous interventions), only two patients (33%) out of the six had a successful outcome while the other four required interventions postoperatively.

Follow-up of all patients ranged from 18 to 36 months (mean 25). In the buccal mucosa group, the nature of the urethral edges did not seem to have an impact on the outcome of the procedure and all patients had successful outcome. In the BAMG group, however, the nature of the urethral edges, we believe, had a definite role in determination of the outcome.

While eight of the nine patients, with one or no previous urethral intervention, had a successful outcome (89%), we only had two successful repairs out of six patients in those with two or more interventions (33.3%). The spongiofibrosis and the lack of healthy edges adversely affected the mucosal growth over the scaffold, which depends totally on the quality of the surrounding urethral mucosa for regeneration.

Although acellular collagen-based grafts may be suitable for partial urethral repair in an onlay fashion, they are ineffective for replacing tubularized segments. De Filippo et al⁷⁹ suggested the use of tubularized collagen matrices, seeded with autologous urothelial and muscle cells to avoid stricture in the neourethra. The use of autologous cells would avoid rejection, wherein a biopsy of tissue is obtained from the host, the cells are dissociated and expanded in vitro, reattached to a matrix, and reimplanted into the same host.^{69,80} These seeded collagen matrices have been tried even for total penile urethra replacement.⁸¹

Clinical examples using the bladder acellular matrix graft in management of urethral stricture

Case 1 Patient presented with totally excised anterior urethra following Swiney's procedure for extensive urethral stricture disease, and voiding through perineal skin inlay. Most of the pendulous urethra was constructed from non-hirsute ventral penile skin using Theirsh-Duplay technique. Three months later the defect between the proximal end of the reconstructed pendulous urethra and the skin inlay (about 12 cm) was bridged by a tube. Half of this tube circumference was formed of buccal mucosa (oriented on the roof) and BAMG (oriented on the floor) (Figure 63.1). The tube was inserted in a tunnel created on the ventral aspect of the corporeal bodies, and its widely spatulated ends were anastomosed to the previously reconstructed pendulous urethra distally and to the skin inlay proximally. This patient had satisfactory outcome at 6 and 18 months of follow-up. Apart from a wide caliber ring at the distal anastomosis, urethroscopy revealed a wide patent urethra and the buccal mucosa regenerated completely over the BAMG scaffold. On biopsy, the BAMG was completely replaced by tissue similar to that of the normal buccal mucosa.

The rationale of using this technique is based upon the fact that a buccal mucosa graft when it takes, will regenerate within the scaffold over the catheter. The catheter was left for 6 weeks. As no definite conclusions could be drawn from a single case, a study is

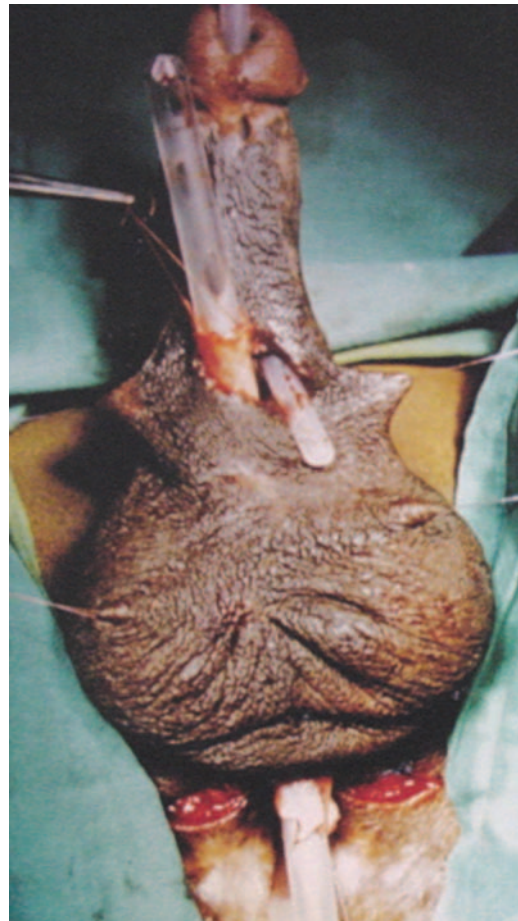
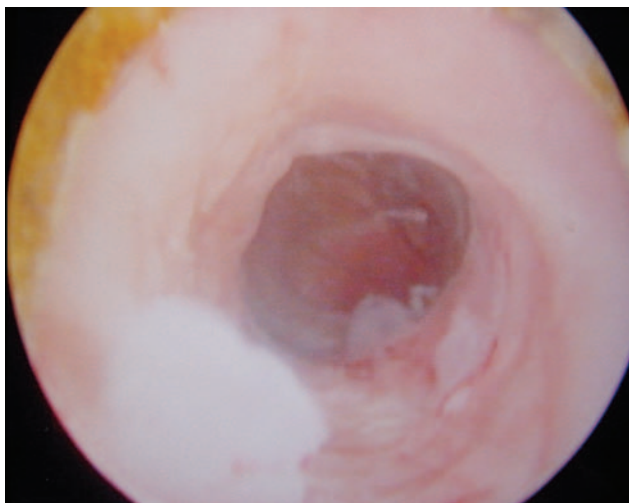
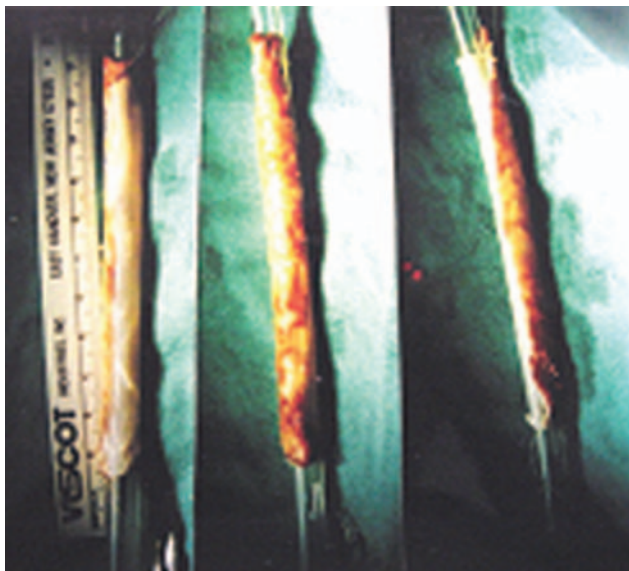


Figure 63.1 A complete urethral tube is formed by combined buccal mucosa and bladder acellular matrix graft. Endoscopic view of the urethra, 6 months after repair, showing adequate caliber of the neourethra and regeneration of buccal mucosa over the whole circumference.

currently underway by the author to verify this concept. This may open the door for a novel approach for management of difficult urethral stricture disease such as balanitis xerotica obliterans/lichen sclerosus in which both genital and extragenital skin are not suitable for urethral augmentation.

Case 2 Patient with a 2 cm severely stenotic segment of distal bulbous urethra. The rest of the urethra was healthy. The segment was completely excised, and the roof strip was anastomosed, and the floor was augmented by BAMG. At 6 months postoperatively, a urethrogram showed widely patent urethra, and at 12 months the patient was without complaint, and the urethrocystoscope showed circumferentially epithelialized urethra (Figure 63.2).

Case 3 This patient had a long bulbopenile stricture. BAMG was used ventrally to augment the urethra. The 6-month urethrogram showed a widely patent urethra (Figure 63.3). The patient is symptom free, with sterile urine.

Case 4 This patient had 12 cm long anterior urethral stricture from the mid-pendulous to the mid-bulbar urethra. Stricturotomy was performed on the floor along the whole length of the stricture. Excision of the narrow mid-bulbar segment and roof strip anastomosis was undertaken. Augmentation of the urethra was performed by patching the floor with BAMG (Figure 63.4). After 28 months the patient was voiding well, had only one attack of lower urinary tract infection, and follow-up urethrocystoscopy at 18 months was patent.

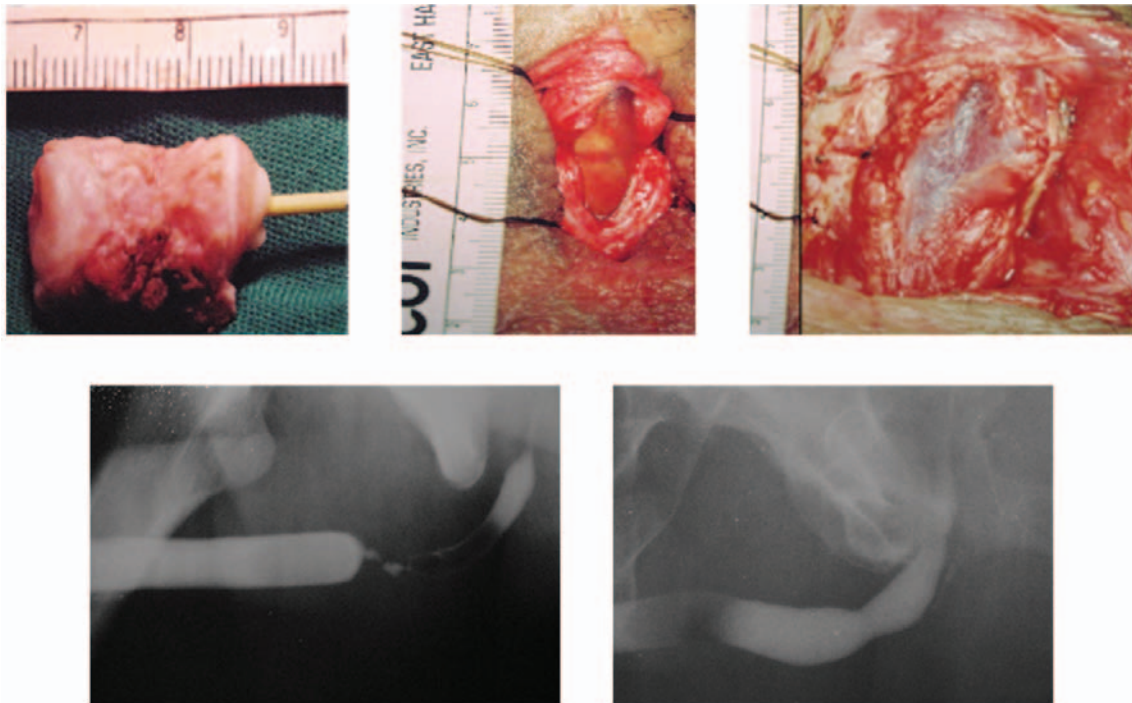


Figure 63.2 The stricture exposed, and the obliterated segment is excised (left). The roof is anastomosed (middle), and the floor is augmented with BAMG (right). Preoperative (lower left) and 6 months postoperative (lower right) urethrogram.

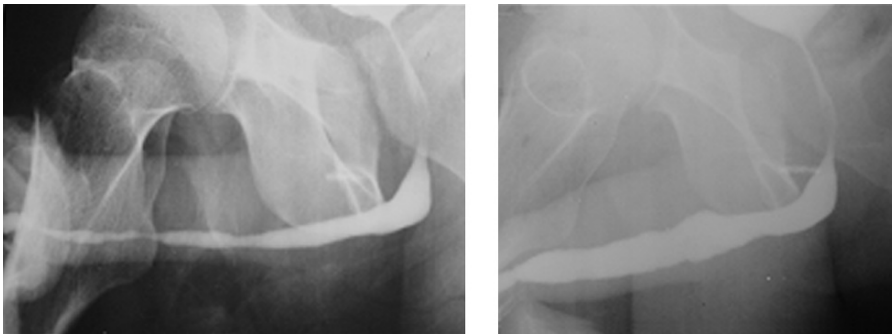


Figure 63.3 Preoperative urethrogram (left) with long anterior urethral stricture, and 6 months postoperative urethrogram (right).

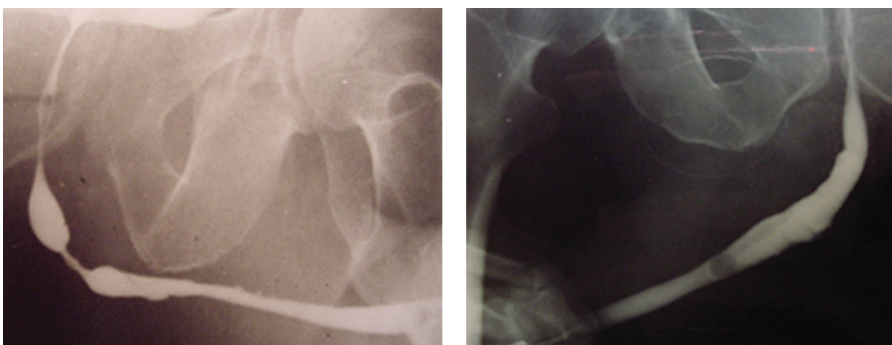


Figure 63.4 The preoperative urethrogram (left), and 6-month follow-up urethrogram.

CONCLUSION

The success of using acellular matrix scaffold grafts for urethral reconstruction depends upon the ability to select host tissue properly so as to optimize the conditions for survival and maximum regeneration of all urethral layers. The urethra, functioning as a conduit, makes it so amenable to replacement by tissue engineering and may make the off-the-shelf graft a real option in the urethroplastician armamentarium.

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64 **Anastomotic contractures after treatment for prostate cancer**

Neil H Grafstein and George D Webster

Currently about one-third of patients newly diagnosed with prostate cancer are treated with radical prostatectomy, an operation that has a low risk of mortality but may have a profound impact on quality of life.¹ Once condemned as a procedure fraught with unacceptable morbidity, radical prostatectomy has experienced a renaissance since Walsh's description of the anatomic approach to prostatectomy. The procedure continues to evolve, most recently including laparoscopic and robotic modifications, in an attempt to reduce its morbidity. Despite these improvements, anastomotic contractures (AC), along with erectile dysfunction and incontinence, remain the most common postoperative complications. In the Medicare population, treatments to relieve bladder neck contractures were the most commonly performed procedures related to complications after radical prostatectomy.² Since the number of patients undergoing radical prostatectomy has dramatically increased and will likely continue to do so in this prostate specific antigen (PSA) era, the urologist must be well versed in the management of the long-term complications associated with the procedure.

AC are reported to occur in 0.8–20% of patients following radical prostatectomy.³ The definition of an AC differs by report and this variability may account for the wide range of prevalence seen in the literature. Studies using patient self-reported questionnaires or Medicare reviews presume an AC to have occurred only if a patient has undergone treatment for the condition, such as dilatation. Alternatively, surgeon reports often define a contracture based on the cystoscopic or radiographic appearance of the anastomosis as seen during an evaluation for urinary symptoms. In some surgeon reports, those patients who are successfully treated with only a single bladder neck dilatation are not included in the definition of AC.⁴ The varying definitions and inconsistency in reporting notwithstanding, ACs occur with sufficient frequency to warrant explicit mention in the informed consent discussion prior to radical prostatectomy.

The hallmark of an AC is the formation of fibrous scar tissue at the vesicourethral anastomosis that encircles the bladder neck and constricts its lumen. The end

result is a fixed anatomic obstruction that incites the constellation of lower urinary tract symptoms common to all forms of bladder outlet obstruction. Patients can present with urinary frequency, urgency, weakened urinary flow, and incomplete emptying. Should severe narrowing of the bladder neck occur patients may ultimately progress to acute urinary retention. The development of a symptomatic AC can negatively impact quality of life; in fact, on self-reported questionnaires, patients with AC were less likely to choose radical prostatectomy again than were those patients who did not develop an AC.⁵ While patients may present at any time, AC are typically detected within the first year after radical prostatectomy and approximately 70% are diagnosed within 6 months of surgery.⁶

There is a well known association between AC and postprostatectomy urinary incontinence. In the Baylor 13-year experience with artificial urinary sphincter (AUS) placement, pre-AUS implantation cystoscopy revealed the presence of a bladder neck contracture requiring transurethral resection in 37% of patients.⁷ This association does not necessarily imply a cause and effect relationship but does have important ramifications on management. For patients with mild postprostatectomy incontinence secondary to sphincteric deficiency, the anatomic obstruction from an AC may be contributing to continence; therefore, treating the AC and eliminating the obstructive element may exacerbate the magnitude of incontinence. At the other end of the spectrum, when high volume urinary incontinence is already present as the primary complaint, the decision to proceed with an anti-incontinence procedure such as an AUS or urethral sling is impacted by the finding of a concurrent AC. Since urethral instrumentation to access an AC can endanger an AUS cuff site or compromise a sling-supported urethra, an AC should be addressed prior to the anti-incontinence procedure. An asymptomatic small caliber AC found incidentally during the incontinence evaluation, which could otherwise be managed conservatively, may need to be addressed in order to avoid future instrumentation after an AUS or sling.⁸

DIAGNOSIS

When postprostatectomy patients present with symptoms suggestive of an AC, cystoscopy is the most valuable diagnostic tool. The vesicourethral anastomosis is evaluated for the caliber of the lumen, and pliability and maturity of the scar. Since a number of patients will undergo treatment for urinary incontinence that is either already present or may result from treatment of the AC, attention should also focus on the endoscopic appearance of the sphincter-active urethra and the bulbar urethra. The health and function of these two areas will be of critical importance in managing urinary incontinence. A circumferentially scarred sphincter-active urethra has negative prognostic implications for the success of a male bulbourethral sling and such patients are better treated with an AUS. Since the bulbar urethra is the optimal location for an AUS cuff, the integrity of the bulbar urethra should also be confirmed at this time in order to properly counsel patients regarding treatment options for concomitant or subsequent urinary incontinence.

Evaluation of urodynamics is not necessary for the diagnosis of an AC but is often performed when urinary incontinence is present. With video-urodynamics the stricture may be seen as a narrowing at the bladder neck on the voiding cystourethrogram but urodynamic evidence of obstruction as defined by Schafer nomogram is seen in only a minority of patients.⁹ The classic pressure-flow measurements are likely absent owing to a combination of the varying degrees of constriction and the Valsalva voiding seen in postprostatectomy patients with sphincteric incontinence. An AC may be discovered incidentally at the time of urodynamics after a failed attempt at passing the urodynamics catheter.

PATHOGENESIS OF ANASTOMOTIC CONTRACTURE

Although the exact pathogenesis of AC has not been defined, a number of factors have been reported to increase the risk of AC formation. Excessive blood loss, pelvic hematoma formation, and vesicourethral anastomotic urinary leakage are widely purported to predispose to AC. Each of these may excite an exaggerated inflammatory response and lead to scarring or fixation of the anastomosis. A history of previous transurethral resection of the prostate (TURP) or radiation has also been reported to increase the risk of contracture development and the risk of complications resulting from the treatment of the AC.

In one series of 467 prostatectomies looking at preoperative comorbidities, *coronary artery disease, current*

cigarette smoking, hypertension, and diabetes mellitus were predictors of contracture development. The association of these conditions with microvascular disease suggests that a contracture may be the end result of ischemia and subsequent fibrosis at the anastomosis.¹⁰

Some patients may have a *predisposition to scar formation*, with AC being the local manifestation of an underlying systemic tendency for excessive scarring. Park et al found that patients with AC had an abdominal incisional scar that was 51% wider than control patients. Interestingly, when the scar width was larger than 10 mm, an eight-fold increase in risk of contracture was observed.⁶

The surgical technique used to create the vesicourethral anastomosis may impact contracture formation. Bladder mucosal eversion, direct mucosa-to-mucosa apposition, and tension-free anastomosis are generally accepted to have decreased the incidence of anastomotic strictures. However, in a recent prospective trial of 100 patients randomized to bladder neck mucosal eversion or no eversion, no statistical difference in contracture rate was demonstrable.¹¹ In fact this step is generally omitted from laparoscopic prostatectomies, with comparable contracture rates when compared with the open approach.¹¹

A larger caliber anastomoses seems to protect against contracture formation, although a precise critical size for the vesicourethral anastomosis is not entirely clear. Catalona et al noted a decrease in contracture rate from 9.6 to 1% by increasing the diameter of the anastomosis from 18 to 22–24 Fr.¹² Similarly, Huang and Lepor found that enlarging the reconstructed bladder neck even further from 22 to 30 Fr was protective against AC formation.¹³

Cystography prior to postprostatectomy catheter removal is often performed to exclude persistent urinary extravasation at the anastomotic site. Patients with continued leakage should be selected for a prolonged period of catheterization. The rationale for this approach is that prolonged catheter drainage does not significantly increase the risk of contracture formation but rather serves to protect against the increased risk of contracture formation due to persistent urine extravasation.^{13,14}

TREATMENT OPTIONS

Dilatation

The initial treatment of an AC is urethral dilatation. This is usually performed in the clinic setting using instillational anesthesia only, and is well tolerated. Calibration with urethral sounds, balloon dilatation,

and filliform and followers are all acceptable methods of dilatation and are likely equally effective. The most important caveat is to create no further injury, making a case for cystoscopically guided placement of a guide followed by sequential dilatation with sounds or a balloon. We generally use cystoscopic guidance to pass a 0.038 inch floppy tip guidewire beyond the stricture and serially dilate over the wire using Goodwin sounds to about 18 Fr.

Ultimately, up to 90% of patients can be successfully treated with dilatations. However, the long-term response to a single dilatation is probably less than 50% and multiple dilatations may be required to maintain patency. The mean time period between dilatations in those patients with recurrence has been reported to be 2.75–4 months.^{3,6} Self catheterization is a useful adjunct to dilatation and may prolong the time interval between formal dilatations. The patient self calibrates with a 16Fr catheter initially on a daily basis and then at increasing intervals until the contracture stabilizes. In fact, a long-term self calibration regimen that is diligently adhered to can maintain urethral patency and obviate the need for further intervention indefinitely.¹⁵

A subset of patients on self calibration may require an anti-incontinence procedure to address either pre-existing stress urinary incontinence or stress incontinence occurring as a result of treatment of the AC. In these authors' experience, chronic self catheterization is not a contraindication to AUS placement and implantation can safely improve continence in these patients; however, optimally the AC should be resolved first.

Endoscopic incision

AC incision performed endoscopically as a primary treatment carries a reported success rate in excess of 90%.¹⁶ With long-term follow-up, Yurkanin et al had a retreatment rate (either dilatation or repeat urethrotomy) of only 13% when urethrotomy was used as the initial therapy. Nonetheless, urethrotomy is usually reserved for those cases refractory to dilatation or for those patients unwilling to undergo multiple dilatations or self catheterization. This relegation to second-line treatment is based on two perceived disadvantages: the need for general or spinal anesthesia and an increased risk of urinary incontinence. The latter has been challenged by multiple studies which have failed to show a decrease in continence level after cold-knife urethrotomy.¹⁷ Appropriate patient selection and meticulous technique can minimize the risk of complications. Only mature scars should be incised and some

suggest that electrocautery should be avoided, although these authors believe that careful bovie incision using a Colling's knife and with careful attention to anatomic landmarks is safe. We prefer to incise at the 3 and 9 o'clock positions with care taken to avoid incising distal to the scar and into the fibers of the sphincter-active urethra. Rectal injury and rectourethral fistula are rare complications that may be prevented by avoiding incision into the floor of the AC where the rectum lies in close proximity.

For the small percentage of patients who develop recurrent contractures that are recalcitrant to multiple dilatations or urethrotomy, an aggressive deep incision or transurethral resection using electrocautery may be necessary to establish and maintain adequate patency.¹⁸ Stress urinary incontinence or exacerbation of pre-existing incontinence will often result from this aggressive endoscopic approach and patients should be counseled accordingly. For the patient with significant pre-existing stress urinary incontinence, management of the contracture with deep electrocautery incision and placement of an AUS, either synchronously or in a staged fashion, are acceptable and effective strategies. At the authors' institution, 25 of 26 patients managed in this fashion remained patent and socially continent with the AUS at long-term follow-up.¹⁹ The one patient who had a stricture recurrence was successfully managed with repeat incision. The drawback to this approach is that should re-treatment of the AC be necessary, instrumentation of the urethra may jeopardize the urethra at the AUS cuff site, predisposing to urethral erosion. This traumatic risk can be minimized by accessing the contracture with a flexible ureteroscope rather than a cystoscope and performing urethrotomy with a holmium laser fiber. However, this procedure is time consuming, offers poor visibility, and does not always lead to adequate clearance of the obstruction. Alternatively, the AUS cuff can be temporarily uncoupled via a perineal incision prior to passage of the cystoscope or resectoscope to avoid subcuff urethral trauma. A staged procedure with initial contracture incision, followed by a surveillance period to confirm patency of the bladder neck, and then AUS implantation has been shown to be equally effective. The obvious advantage to the staged approach is that the response to contracture incision can be evaluated prior to proceeding with the AUS, thus avoiding repeat instrumentation with an AUS in place. However, during this waiting period the patient is forced to tolerate a prolonged period of incontinence while they await definitive management with an AUS. Ultimately, the decision for simultaneous or staged AUS placement should be based on the stability, caliber, and

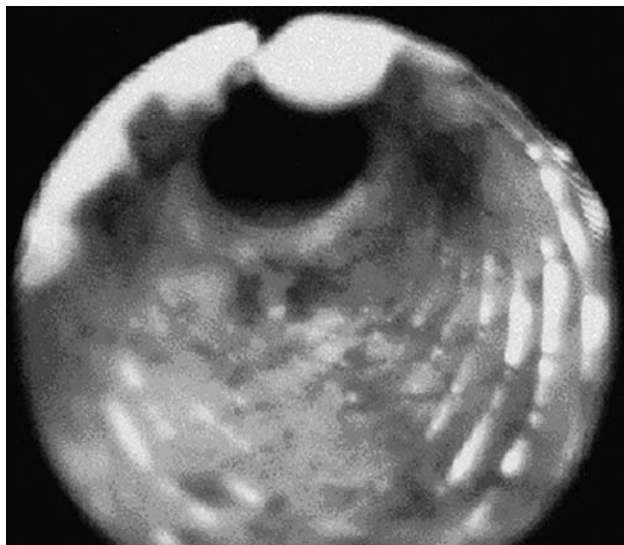


Figure 64.1 Cystoscopy shows stent placed across previously obliterated anastomosis after recanalization.

maturity of the AC as determined by history and cystoscopic appearance. For example, an incontinent patient with a less than 5 Fr contracture that has rapidly recurred despite multiple dilatations or incisions is probably best served by a staged approach with patency of the bladder neck confirmed prior to proceeding with AUS placement.

Stenting of the recalcitrant anastomotic contracture

Patients with recurrent intractable contractures or those patients unwilling to perform self calibration can be salvaged with a Urolume® urethral stent (American Medical Systems, Minnetonka, Minnesota). Elliot and Boone published results of successful resolution of obstruction in eight of nine stented patients.²⁰ Anoai et al achieved long-term patency with a single Urolume stent in 64% (14/22 patients) and in an additional 18% of patients with a second tandem stent.²¹

An appropriate combination of dilatation, incision, and resection of scar tissue is performed to achieve a caliber of 24 Fr. Care must be taken to leave a hemostatic smooth surface to accommodate the urethral stent. Then, using an AMS Urolume applicator, a stent is placed across the AC, the proximal end of the stent is anchored just at the bladder neck overlapping healthy tissue. The stent size should be selected to traverse the entire length of the stricture (Figure 64.1).

Unfortunately, the smallest stent manufactured is 1.5 cm in length which will invariably traverse the

sphincter-active urethra and render the overwhelming majority of patients severely incontinent. This accounts for the near 100% incontinence rate in all published series. Therefore, implicit in the decision to proceed with Urolume stenting of an AC is the patient's willingness to proceed with an anti-incontinence procedure, either concomitantly or as a staged procedure. The most viable option for the resulting incontinence of this high magnitude is an AUS. Elliot and Boone implanted the AUS at a minimum of 3 months after stenting and noted a decrease in pad usage from 6.5 to 0.7 pads/day and an 88% patient satisfaction rate.²⁰ Anoai et al achieved continence (0–1 pad/day) in 19 of 20 patients with no difference in outcome for patients implanted in a staged or synchronous fashion. The only patient with continued incontinence despite AUS placement had a history of radiation therapy.²¹

Encrustation or re-obstruction with tissue ingrowth, hematuria, and stent migration can complicate Urolume stenting. These potential complications of Urolume stents are well reported and do occur with some frequency. Therefore, we prefer to attempt at least one recanalization followed by self calibration before committing to Urolume stenting. Stent obstruction due to tissue ingrowth occurs in approximately 30% of patients.^{21,22} Such ingrowth can be effectively treated with a holmium laser and, if an AUS has been implanted, the laser fiber should be introduced via a flexible ureteroscope.

The obliterated outlet

A postprostatectomy patient presenting with a complete obliteration of the lumen can be the most challenging of ACs. Placement of a suprapubic cystostomy catheter should be the initial intervention to establish drainage. Definitive treatment options then include indefinite suprapubic tube drainage, an endoscopic recanalization, urinary diversion with creation of a continent (or incontinent) abdominal stoma, or formal bladder neck reconstruction via open surgery. Urinary diversion is certainly effective in circumventing the devastated bladder outlet, but it is a major surgical undertaking and it carries with it the risk of metabolic complications, altered body image, and permanent need for self catheterization. Open surgical bladder neck reconstruction techniques have been described and are reportedly effective, albeit in small case reports. Using a combined abdominal and perineal approach, and possibly necessitating partial pubectomy, a patient must be willing to undergo a lengthy operation and accept a

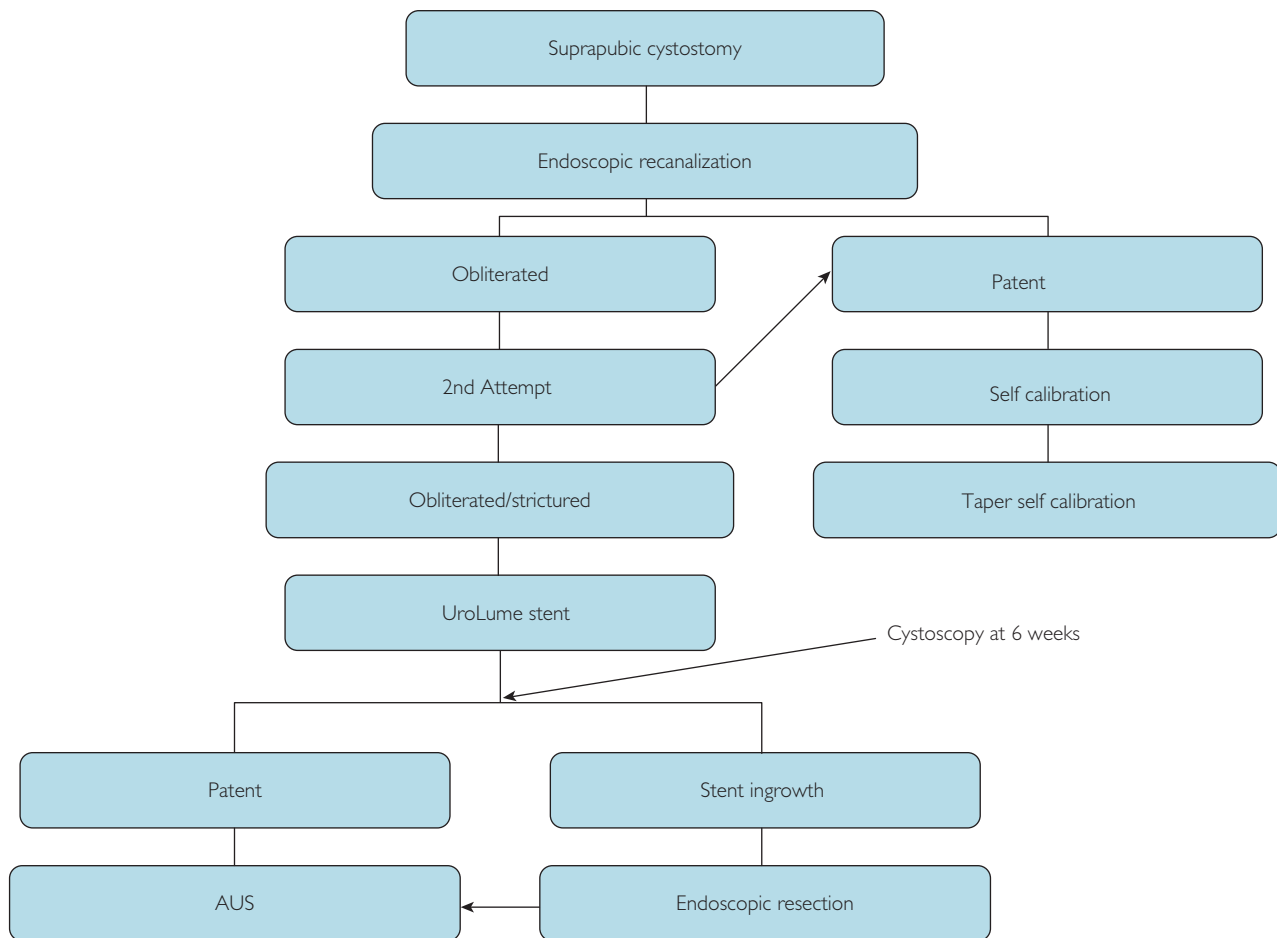


Figure 64.2 Suggested algorithm for management of the obliterated bladder outlet after radical prostatectomy. AUS, artificial urinary sphincter.

substantial risk of morbidity including erectile dysfunction and rectal injury.²³ We prefer a less invasive, endoscopic strategy to the oblitative or refractory AC.

Endoscopic recanalization

We have frequently re-established vesicourethral continuity using a combined antegrade and retrograde endoscopic approach.³ A 19 gauge sternal guidewire is loaded into the working channel of a rigid cystoscope which is advanced retrogradely up the urethra to the anastomotic obliteration. A second cystoscope is then passed into the bladder through the suprapubic tract to identify the characteristic dimple of the scarred bladder neck. The sternal wire is then pierced through the obliterating scar with the aim of emerging into the bladder through the bladder neck scar where its entry is observed by the suprapubic endoscopist. Multiple attempts are often required, even by the experienced endoscopist, to successfully traverse the scar in the proper location. There is

a tendency for the stiff sternal wire to tunnel under the trigone and so the guidewire must be directed upward by depressing the access angle of the retrograde endoscope. Once accomplished cold knife urethrotomies are made at the 3 and 9 o'clock positions guided by the wire. The opening is then enlarged to accommodate a 22 Fr catheter which is left indwelling, along with the suprapubic catheter, for a minimum of 7–10 days. The urethral catheter is then removed and the patient is started on a diligent self-calibration program with a 16 Fr catheter. The suprapubic catheter is clamped and voiding trials given. Intraoperative recanalization was successful in 100% of cases at our institution. Of patients treated in this fashion 17% remained patent with self calibration and did not undergo further management of incontinence. The remaining patients re-obiterated but were successfully recannulated with a repeat procedure before total obliteration occurred and was then followed by stenting of the contracting area with a UroLume stent.²¹ A suggested algorithm for managing the obliterated outlet is outlined in Figure 64.2.

CONCLUSION

The formation of an AC following radical prostatectomy is not an infrequent occurrence, and is particularly prevalent among the subset of patients with postprostatectomy incontinence. Fortunately, most vesicourethral ACs can be successfully managed with dilatation or endoscopic incision, which are procedures well within the armamentarium of the urologic community. However, a number of patients will present with obliterative or refractory anastomotic strictures and will warrant innovative reconstructive approaches.

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65 Reconstructive surgery for pelvic floor relaxation

Christian Twiss, Veronica Triaca, Ramdev Konijeti, and Shlomo Raz

INTRODUCTION

Reconstructive surgery for pelvic organ prolapse remains a challenge even for the most seasoned pelvic surgeon, requiring a detailed knowledge of pelvic anatomy and the supportive structures of the uterus and vagina. Numerous approaches and techniques, each with its own distinct advantages and disadvantages, exist for the repair of each vaginal compartment. Ultimately, regardless of approach, there remains a set of core goals of pelvic reconstruction which include the restoration of normal vaginal depth, caliber, and axis; prevention of further pelvic organ prolapse; and restoration and maintenance of normal bladder, bowel, and sexual function. This chapter reviews the applied anatomy and common reconstructive techniques employed to repair each vaginal compartment in order to achieve these surgical goals.

REPAIR OF ANTERIOR VAGINAL PROLAPSE

Surgical goals of anterior repair

Cystocele primarily results from defects in level 1 and level 2 vaginal support according to DeLancey's classification.¹ The pubocervical fascia, a condensation of the endopelvic fascia, provides the level 2 support of the bladder via its lateral attachments to the arcus tendineus fascia pelvis. Level 1 support of the bladder base is provided by the fusion of the pubocervical fascia to the cardinal-uterosacral ligament complex which is affixed to the pelvic side wall and sacrum. A straightforward visualization of the pubocervical fascia is a trapezoid anchored at its base to each ischial spine, laterally to the arcus tendineus fascia pelvis, and distally to the urethral supportive ligaments² (Figure 65.1). It is important to be mindful that there is, in fact, no true vaginal fascia. The pelvic structures commonly termed 'fascia' are simply condensations of connective tissue separating the vagina from the bladder or rectum.

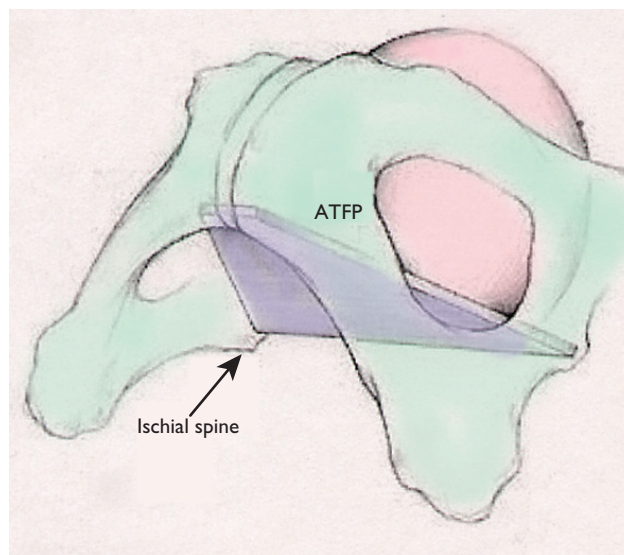


Figure 65.1 The trapezoidal configuration of the pubocervical fascia. ATFP, arcus tendineus fascia pelvis. Adapted from reference 2. Reproduced with permission of Dr John Delancey. All rights reserved.

An important anatomic distinction that governs repair of anterior prolapse is the difference between central and lateral anterior defects. A central defect cystocele results from weakness of the pubocervical fascia itself resulting in a large central anterior vaginal bulge. The lateral defect cystocele results from detachment of the pubocervical fascia from its fixation point to the arcus tendineus fascia pelvis and the fascia of the levator ani. In reality, anterior defects often involve a combination of both types of defects.³

Another important concept in anterior repair is the provision of apical support. In patients with a uterus, a weakened cardinal-uterosacral complex results in descent of the uterus and vaginal apex. The loss of level 1 support results in poor support of the bladder base and contributes to cystocele formation. In patients who have undergone hysterectomy, both a weakened cardinal-uterosacral complex and detachment of the vaginal apex from these structures can contribute to the loss of level 1 vaginal support. The loss of level 1 support causes rotational, downward

descent of the base of the trapezoid-shaped pubocervical fascia. Restoring the trapezoid base will often repair the cystocele. Many believe that the central defect is rarely actually the primary problem in anterior prolapse.

Thus, in patients with significant cystocele there are four defects: distally, the loss of urethral support; proximally, descent of the vaginal apex; lateral defects; and a central defect. Poor urethral support (regardless of a patient's continence) is present in the majority of the patients with significant cystocele. All four defects should be repaired. In our experience, the overwhelming majority of patients with significant cystocele also have concomitant prolapse of the apical and posterior compartments.

A major problem with anterior repair, in general, is the large recurrence rate of significant cystocele (more than 25% in some series, see below). Therefore the use of surrogate material has become commonplace in repairing anterior vaginal prolapse.

Approaches to anterior repair

Both vaginal and abdominal/laparoscopic approaches to anterior repair exist, and there is no current consensus on the optimal approach. Since anterior repair is often performed in conjunction with other site specific repairs, such as repair of the vaginal apex, the approach to apical repair will often dictate the approach to anterior repair as well. Ultimately, the comfort and experience level of the surgeon in combination with the various defects that require repair will dictate the approach. Two important points to consider are that it is difficult to repair central defect cystoceles via the abdominal approach, often necessitating a concurrent vaginal procedure, and, in general, the vaginal approach results in fewer wound complications, less postoperative pain, shorter convalescence, and less overall financial burden.^{4,5} However, the development of the laparoscopic paravaginal repair may have implications for the latter point. There is currently a paucity of randomized, controlled trials providing firm evidence favoring any approach. Also one must bear in mind that the literature, in general, suffers from a lack of standardization of outcomes, particularly with regard to the definition of surgical success.

Vaginal approaches to anterior repair

Anterior colporrhaphy Various techniques of anterior colporrhaphy exist, but they all involve a midline vaginal incision followed by dissection of the vaginal wall

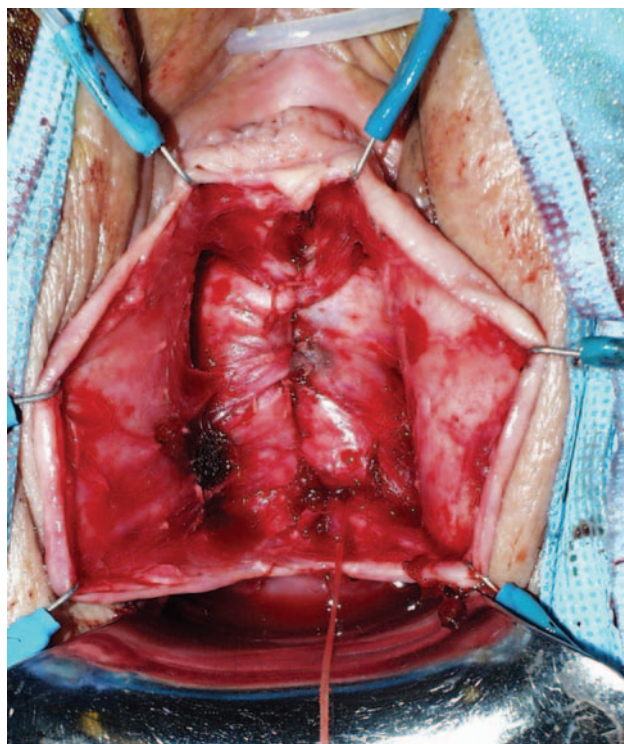


Figure 65.2 Anterior colporrhaphy for central defect cystocele. The attenuated pubocervical fascia is reapproximated in the midline.

from the pubocervical fascia and simple midline plication of the weakened pubocervical fascia (Figure 65.2). This type of repair addresses central defect cystoceles, but does not address lateral defects. The primary criticism of this technique is that the already weakened pubocervical fascia is the primary basis of the repair, thereby exposing the patient to the potential risk of recurrence. Despite this, large series report success rates between 80 and 97%.⁶⁻⁸ However, two recent randomized trials comparing non-mesh with mesh anterior repairs reported short-term success rates of 37–57% without the use of synthetic mesh.^{9,10} The procedure is relatively safe with minimal complications, and the primary risk is recurrence.

Vaginal paravaginal repair The goal of paravaginal repair is to repair a lateral defect cystocele by reapproximating the pubocervical fascia to the arcus tendineus fascia pelvis. This can be a unilateral or bilateral repair. Via a midline anterior vaginal incision, the vaginal wall is separated from the pubocervical fascia laterally until the pubic bone is reached. The endopelvic fascia is opened, and the defect is identified. Typically, permanent three-point sutures are then placed, incorporating the arcus tendineus fascia pelvis, the pubocervical fascia plus full-thickness vaginal wall

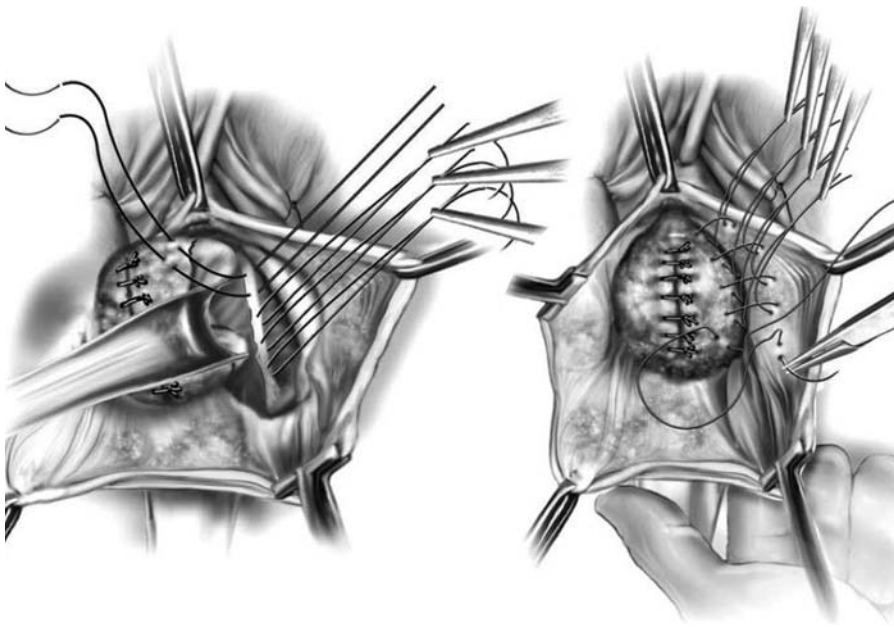


Figure 65.3 Vaginal paravaginal repair for lateral defect cystocele. The pubocervical fascia is sutured to the arcus tendineus fascia pelvis and the vaginal wall. A central defect cystocele has also been repaired in the midline. From reference 13 with permission. Reproduced with permission of Springer-Verlag Press. All rights reserved.

(excluding the epithelium), and the endopelvic fascia. The sutures are then tied only after all have been placed (Figure 65.3).

The largest series report success rates between 78 and 99%,^{11,12} and the technique has the advantages of avoiding the morbidity of a laparotomy and facilitating concurrent transvaginal repair of any central defect that is present. However, the limited exposure carries increased risk of damage to and hemorrhage from the obturator and pudendal neurovascular pedicles.^{3,11} Ureteric injury has also been reported.¹³ However, there are no randomized trials comparing vaginal with abdominal paravaginal repair.

Transvaginal mesh repair Owing to high recurrence rates and the conceptual problem of utilizing already weakened fascia for the repair of anterior defects, various synthetic and biologic materials have been utilized for anterior repair. Placement of artificial materials, such as cadaveric fascia lata, polyglactin mesh, and polypropylene mesh, has been done to augment the reconstruction. The overall reported success rates for the repair of cystocele using graft materials is between 42 and 100%.¹⁴ However, the use of graft materials carries the two closely linked risks of infection and erosion which are reported in between 6.5 and 25% of cases depending upon the material used.¹⁵ Currently, due to a paucity of well designed prospective randomized trials, definitive recommendations for the use of graft materials in vaginal reconstructive surgery cannot be made.¹⁴

Our practice is to use a soft polypropylene mesh because this material is non-absorbable, flexible, and

strong. Moreover, it has a large pore size which allows ingrowth of endogenous tissue for remodeling, chemotaxis of macrophages and fibroblasts, and angiogenesis.^{16,17} This property is important for the incorporation of the mesh into host tissues as opposed to exclusion and encapsulation, and it facilitates immune surveillance for the prevention of graft infection.

Our transvaginal four-point technique using soft polypropylene mesh to repair grade IV cystocele involves (1) approximation of the perivesical fascia in the midline with horizontal mattress sutures for the central defect, (2) exposure and approximation of the cardinal-uterosacral ligaments to the midline for support of the bladder base proximally, (3) support of the bladder neck and urethra with a suburethral sling, and (4) repair of central and lateral defects using a sheet of polypropylene mesh as described below. It must be emphasized that a concurrent procedure is always undertaken to support the vaginal apex.

The patient is placed in dorsal lithotomy position and anterior vaginal exposure is provided by labial sutures, a Scott retractor, and a weighted speculum. A suprapubic tube is placed using a Lowsley retractor. If uterine descent is present, a vaginal hysterectomy is first performed as described later in this chapter.

A distal urethral polypropylene sling is placed (Figure 65.4). For this, two lateral oblique incisions are made at the level of the distal urethra. Sharp and blunt dissection are then used to create an entrance into the retropubic space bilaterally. A puncture is then made suprapubically at the level of the pubic symphysis. Between the two lateral vaginal wall

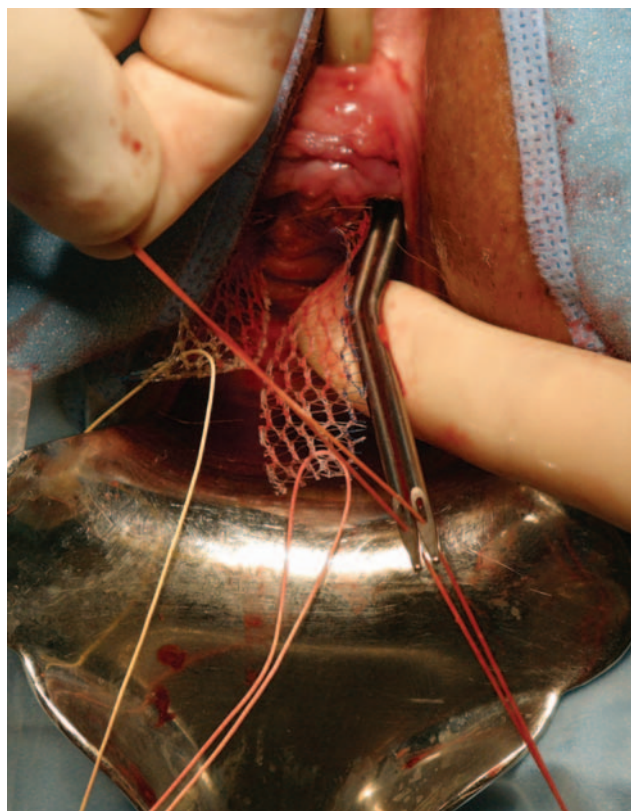


Figure 65.4 Placement of distal urethral polypropylene sling (DUPS). The polypropylene sling has been placed through the tunnel between the vaginal wall and pubocervical fascia. The double-pronged needle passer is used to pass the sling sutures through the retropubic space into the suprapubic incision.

incisions, a suburethral tunnel is created between the vaginal wall and urethropelvic fascia. A 1×10 cm soft polypropylene mesh sling is then passed through the tunnel with a 0-0 polyglactin suture anchored to either end. The Raz double-pronged passer is passed through the suprapubic puncture and brought out through one of the vaginal incisions under finger guidance. The needle passer is then used to pass the ipsilateral suture ends through the suprapubic incision and the same process is repeated on the contralateral side. The anchor sutures to the sling are tied ipsilaterally without tension. To ensure a tension-free sling, two Allis clamps are used to grasp the sling on both sides at the level of the urethra. The clamps are held laterally in a horizontal plane while the sutures are tied at the level of the symphysis. The vaginal incisions are closed with 3-0 polyglactin sutures.^{18,19}

Attention is then turned to repair of the cystocele. First, a midline incision is made transvaginally from the level of the bladder neck to the cuff of the vagina. Sharp dissection with scissors is then performed to

dissect the vaginal wall from the pubocervical fascia laterally toward the descending rami of the symphysis. Apically, the dissection should be done to the level of the uterosacral ligaments. Any coexisting prolapse should be addressed at this time prior to completion of the anterior repair.

Repair of the central defect is completed next. This is done with 3-0 polyglactin horizontal mattress sutures to approximate the pubocervical fascia, as in standard colporrhaphy. This maneuver is performed solely to reduce the central defect in order to facilitate placement of the mesh, which provides the strength to the repair.

The lateral pelvic wall is then exposed for the placement of the lateral cystocele sutures. Two-zero polyglactin sutures are placed in the infralevator obturator fascia on either side (Figure 65.5A). Placement of the lateral sutures in this location, parallel and slightly inferior to the arcus tendineus, avoids the need to enter the retropubic space and all of the risks inherent in this. The apical suture includes the uterosacral ligaments. A 5×5 cm soft polypropylene mesh disk is placed and secured with the aforementioned sutures (Figure 65.5B). The mesh is fixed distally to the bladder neck in two places with the 3-0 polyglactin sutures. Coexistent rectocele is addressed and repaired at this stage.^{20,21}

Abdominal techniques

The abdominal paravaginal repair can be approached via the open or laparoscopic route with the same goal as the vaginal technique: using permanent sutures to reapproximate the pubocervical fascia and vaginal wall to the arcus tendineus fascia pelvis (Figure 65.6). A major drawback of the abdominal approach is that it is difficult to repair a central defect cystocele via this approach. The classic open retropubic approach was popularized by Richardson et al²² and is more straightforward than the transvaginal approach due to easier visibility of the structures involved. The reported success rates in large series range from 95 to 97%.^{22,23} While the open abdominal approach incurs the morbidity of a laparotomy, it carries a lower risk of hemorrhage.²⁴ The risk of urinary tract injury and postoperative voiding dysfunction are relatively low, both within the 0–5% range.²⁴

The technique of laparoscopic paravaginal repair offers the additional advantage of avoiding the morbidity of laparotomy.²⁵ The repair maneuvers are essentially identical to the open approach but require the additional skills of general laparoscopy and laparoscopic suturing. Only limited data are available on success rates and complications. A recent study by Ross

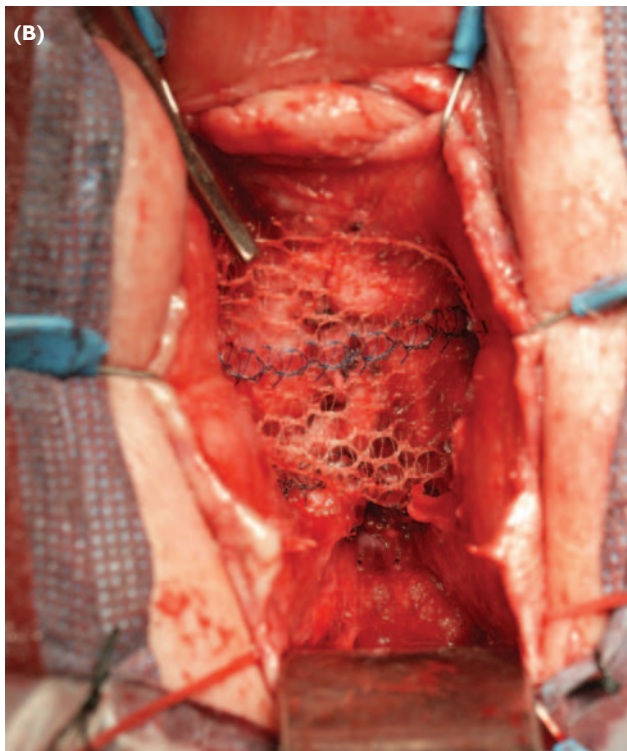
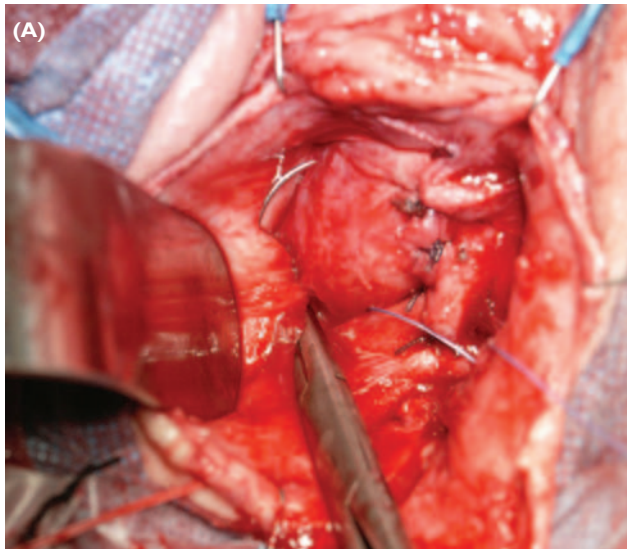


Figure 65.5 Transvaginal mesh cystocele repair. The central defect has already been reduced by simple anterior colporrhaphy. (A) Two-zero polyglactin sutures are placed into the infralevator obturator fascia bilaterally. (B) A 5 × 5 cm disc of soft polypropylene mesh is sutured into place with the above sutures, and it is also affixed to the uterosacral ligaments and the bladder neck. Reproduced with permission of Dr John Miklos. All rights reserved.

and Preston²⁶ reports a 25% recurrence rate of cystocele at 5 years of follow-up. However, the majority of recurrences were central, and only 5% of patients had recurrence of lateral defect cystocele. Complications

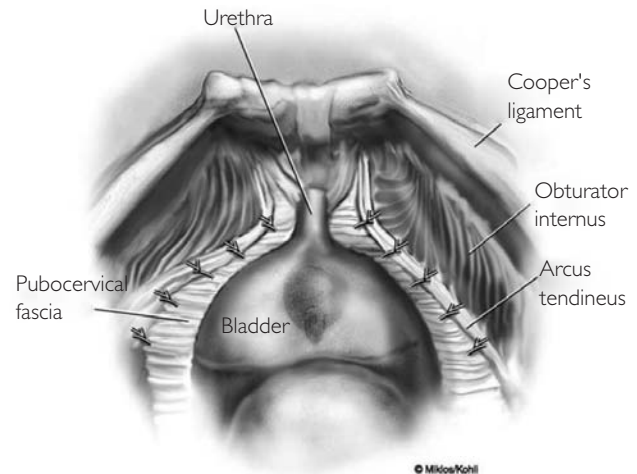


Figure 65.6 The abdominal paravaginal repair. The pubocervical fascia is sutured to the arcus tendineus fascia pelvis via a retropubic approach. From reference 25, with permission.

appear to be relatively low with rates of urinary tract injury similar to those for the open approach.²⁷

No randomized trials exist to compare the efficacy of isolated vaginal with isolated abdominal repair of anterior vaginal wall prolapse.²⁸ Nor do any randomized trials exist comparing vaginal with abdominal or laparoscopic approaches.²⁸

Concomitant urethral suspension

The provision of level 3 urethral support at the time of prolapse repair remains controversial. Clearly, patients suffering from stress urinary incontinence benefit from this intervention. However, a case-control study by Goldberg et al²⁹ demonstrated that addition of a pubovaginal sling to anterior colporrhaphy reduced the cystocele recurrence rate by 50%. It is for this reason that our transvaginal four-point mesh repair of cystocele incorporates simultaneous placement of a suburethral sling. While there are concerns of de novo voiding dysfunction and urinary retention, recent studies indicate that when sub-urethral support procedures are added to reconstructive surgery for prolapse, rates of postoperative stress incontinence and voiding dysfunction are low.^{30–32}

REPAIR OF VAGINAL VAULT PROLAPSE

Surgical goals of apical repair

Prolapse of the uterus and vaginal vault as described in the anatomic study of DeLancey¹ is a defect in level 1

support of the uterus and/or vaginal vault. Support of these structures is primarily provided by the cardinal and uterosacral ligaments which suspend the cervix to the lateral pelvic walls and sacrum.¹ Even in cases of post-hysterectomy vault prolapse, the typical cause is either weakness of the level 1 supportive structures or a separation of the vaginal apex from these supportive structures.

Enterocoele results when peritoneal contents herniate between the bladder and rectum.³³ Enterocoele is commonly associated with prolapse of the vaginal vault, and should be repaired simultaneously when encountered.

Thus, the surgical goals of repair of uterine/vault prolapse are to reconstruct the supportive structures of the uterus and vaginal vault (with possible simultaneous hysterectomy); to reconstruct and maintain vaginal depth, caliber, and axis; and to correct concurrent enterocoele and/or prevent its future occurrence.

Non-uterine sparing techniques

In patients with a uterus, the decision to perform a hysterectomy must first be made as it will often dictate the ultimate approach to repair. Classical teaching promotes concurrent hysterectomy when prolapse occurs after completion of childbearing. Whether concurrent hysterectomy actually reduces the recurrence rate of prolapse is not definitively proven, but it remains accepted practice, worldwide. However, menorrhagia and/or fibroid uterus, metrorrhagia, the continued need for contraception, and both uterine and cervical cancer surveillance remain only a few of the many potential indications for hysterectomy at the time of prolapse repair.

A major concern is the possible effect of hysterectomy on sexuality and sexual function. While there appear to be sound theoretical reasons for sexual dysfunction to develop in hysterectomized women (such as possible vaginal shortening and disruption of the inferior hypogastric plexus),^{34,35} there are few data to suggest that hysterectomy actually worsens sexual function. Rather, current studies suggest a positive effect of hysterectomy on sexual function, coital frequency, and dyspareunia.^{34,36–39} However, patients should still be counseled that although the majority of patients experience no change or improved sexual function after hysterectomy, about 10–15% will experience sexual dysfunction after hysterectomy.³⁴

There are three basic approaches to hysterectomy for benign disease: abdominal, vaginal, and laparoscopic. The surgical approach to hysterectomy is ultimately determined by the experience and comfort level of the

surgeon, but there are several additional considerations such as the possible presence of concurrent cancer or benign pathology, uterine size/fibroid uterus, concurrent adnexal pathology, and possible or known presence of pelvic adhesions and/or known obliteration of the cul de sac. A decision on preservation of the adnexa must also be made prior to hysterectomy.

Abdominal approach

Abdominal hysterectomy is the most common type of hysterectomy performed in the US.⁴⁰ This approach is most applicable for cases of a large uterus, simultaneous ovarian pathology, or a known or possible history of pelvic adhesions. While this technique is rapid,⁴¹ randomized, double-blind studies have demonstrated that abdominal hysterectomy incurs greater blood loss, greater postoperative pain, longer hospital stay, and a longer time to return of normal activities than both the vaginal route and the laparoscopic route.^{41–46} Additionally, postoperative pyrexia and infection rates are higher for the abdominal approach compared with the vaginal and laparoscopic approaches.^{42,47}

Supracervical hysterectomy

The supracervical or subtotal hysterectomy is a cervical sparing hysterectomy in which the uterine corpus is removed either abdominally or laparoscopically, leaving the cervix in place. Proponents of the procedure argue that there is improved urinary and sexual function with the subtotal technique, but this perception is primarily based on non-randomized studies.^{35,48} A large, randomized, double-blind trial by Thakar et al,⁴⁹ and a recent high quality Cochrane meta-analysis⁵⁰ suggest no difference in postoperative sexual, urinary, or bowel function between the two techniques. Additionally, supracervical hysterectomy alone also does not address the attenuated cardinal-sacrouterine complex, and must be accompanied by a vault suspension procedure to reduce the risk of postoperative prolapse of the cervix and vaginal vault. An additional consideration is the approximately 7% rate of continued cyclical bleeding from the cervical stump.⁴⁹

Laparoscopic approaches

Various techniques of laparoscopic hysterectomy have been developed which offer several theoretical surgical advantages including less invasiveness than the open abdominal technique, the opportunity to diagnose and treat other intra-abdominal pathology at the time of hysterectomy (e.g. endometriosis), and the ability to perform adnexal surgery at time of hysterectomy.

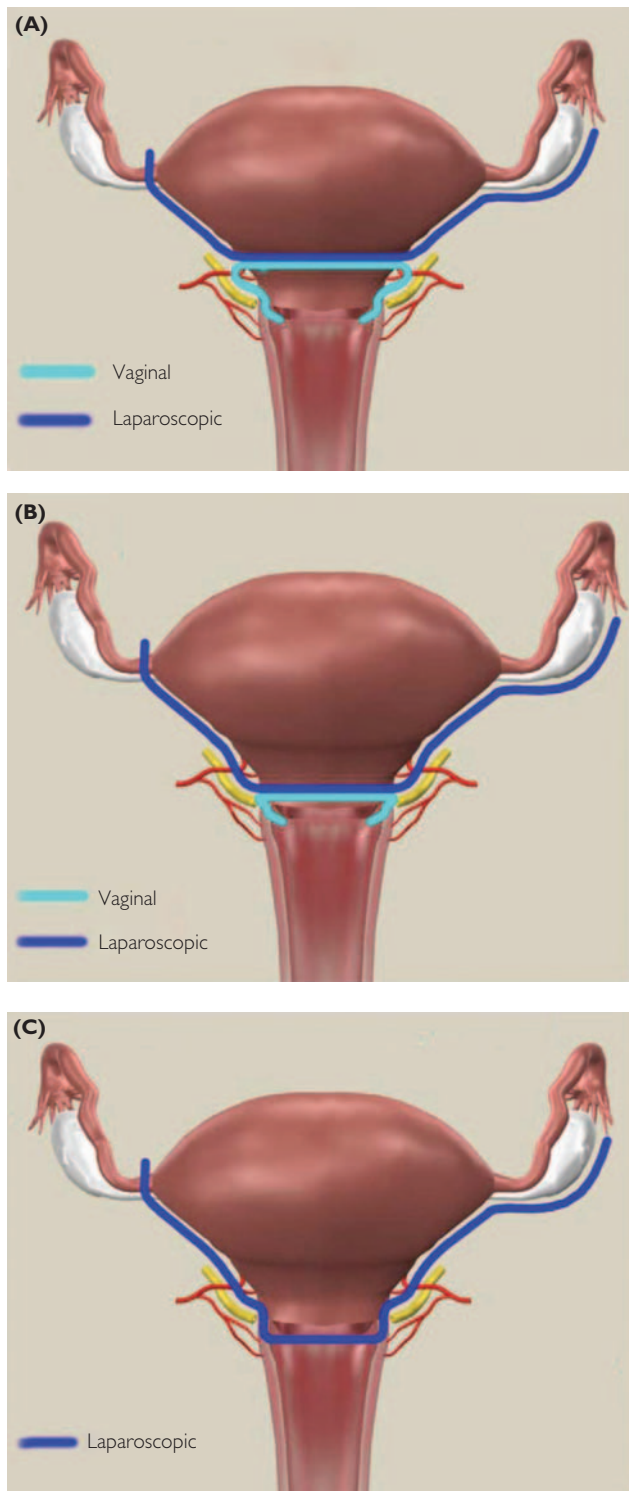


Figure 65.7 Limits of laparoscopic and vaginal dissection: (A) laparoscopic assisted vaginal hysterectomy (LAVH), (B) laparoscopic hysterectomy (LH(a)), and (C) total laparoscopic hysterectomy (TLH). From reference 41, with permission. Reproduced with permission of Dr Ray Garry. All rights reserved.

Garry⁵¹ has proposed three simple, anatomic categories of laparoscopic hysterectomy as it applies to benign uterine disease (Figure 65.7): (1) laparoscopic assisted vaginal hysterectomy (LAVH) in which laparoscopic dissection is used to ligate all structures above the uterine artery while the uterine artery and cardinal-sacrouterine complex dissection is completed vaginally; (2) laparoscopic hysterectomy (LH(a)) in which all the structures above and including the uterine artery are ligated laparoscopically, and the remainder of the dissection is completed vaginally; (3) total laparoscopic hysterectomy (TLH) in which the entire dissection is performed laparoscopically. All three of these variations fall under the umbrella term of 'laparoscopic hysterectomy' (LH). The abbreviation LH(a) is commonly used to distinguish the specific surgical technique to which it refers from the general abbreviation for laparoscopic hysterectomy 'LH'.⁴¹

The current evidence suggests several advantages of LH over open abdominal hysterectomy including significantly less pain and bleeding, and a shorter hospital course with faster return to normal activities after surgery.^{41,47} However, LH has been shown to incur longer operative times, higher cost, and, more significantly, a higher overall rate of urinary tract injury compared with the open abdominal approach in the recent comprehensive Cochrane meta-analysis of surgical approach to hysterectomy for benign disease.⁴⁷ Thus, the advantages of the minimally invasive technique are somewhat offset by the above drawbacks.

Additionally, while the evidence shows that LH does appear to lead to increased ability to diagnose concurrent pelvic pathology compared with the vaginal approach (15% versus 5%),⁵² this perceived advantage remains theoretical as there is no evidence suggesting improved outcomes as a result. Ideally, one would want to diagnose concurrent pelvic pathology preoperatively before surgical planning which is why we routinely obtain a preoperative pelvic magnetic resonance imaging scan to assess for uterine or adnexal pathology, or evidence of pelvic endometriosis as part of the diagnostic work-up for pelvic prolapse.

The ability to perform concomitant adnexal surgery is a valid consideration when considering laparoscopic versus vaginal hysterectomy. However, there is clear evidence that oophorectomy can be completed transvaginally concurrent with vaginal hysterectomy in the overwhelming majority of cases (91%).⁵³ This point remains controversial and needs further evaluation via randomized trials.

Vaginal hysterectomy

The evidence suggests that vaginal hysterectomy, when feasible, is the preferred method of hysterectomy for benign uterine disease.⁴⁷ This is particularly true in the case of correction of pelvic prolapse in which the anterior and posterior vaginal compartments often require simultaneous repair. One of the most important findings of the Cochrane meta-analysis⁴⁷ is that no outcomes are significantly worse for vaginal hysterectomy compared with any other form of hysterectomy. Additionally, vaginal hysterectomy is faster and less costly than laparoscopic hysterectomy, and there are no data favoring LH over vaginal hysterectomy when vaginal hysterectomy can be safely performed.⁴⁷ Thus, a mastery of the vaginal hysterectomy is tantamount for surgeons routinely dealing with pelvic organ prolapse. Our technique for vaginal hysterectomy is described below.

Patients are given prophylactic broad spectrum antibiotics, placed in the high lithotomy position, and the vagina is prepared with iodine antiseptic solution. A weighted speculum, labial retraction sutures, and a Scott ring retractor are used to provide optimal exposure of the vagina. The cervix is grasped with two Lahey clamps which are kept in a fixed anterior-posterior position such that there is no inadvertent rotation of the cervix during dissection.

The cervix is circumscribed approximately 1 cm from the os, and the vesicouterine space is developed sharply between the bladder and uterus. The peritoneum of the anterior cul de sac is purposely not opened at this point to avoid descent of the bowel into the operative field. Next, the cul de sac is opened posteriorly. Heaney retractors are then placed into the vesicouterine space and the posterior cul de sac, thereby exposing the cardinal-sacrouterine complex on each side of the cervix (Figure 65.8). The cardinal and sacrouterine ligaments are exposed using a large right angle clamp and are cross-clamped using a large Phaneuf clamp approximately 1 cm from their cervical attachment. Next, the ligaments are ligated using a 0-polyglactin suture and divided. The uterine pedicles are similarly divided and all the suture ends are kept long and clamped.

Next, the uterine fundus is manually everted posteriorly and brought out of the introitus, followed by opening of the anterior peritoneal fold (anterior cul de sac) over the surgeon's finger. Finally, the broad ligaments are clamped with a large Phaneuf clamp and oversewn

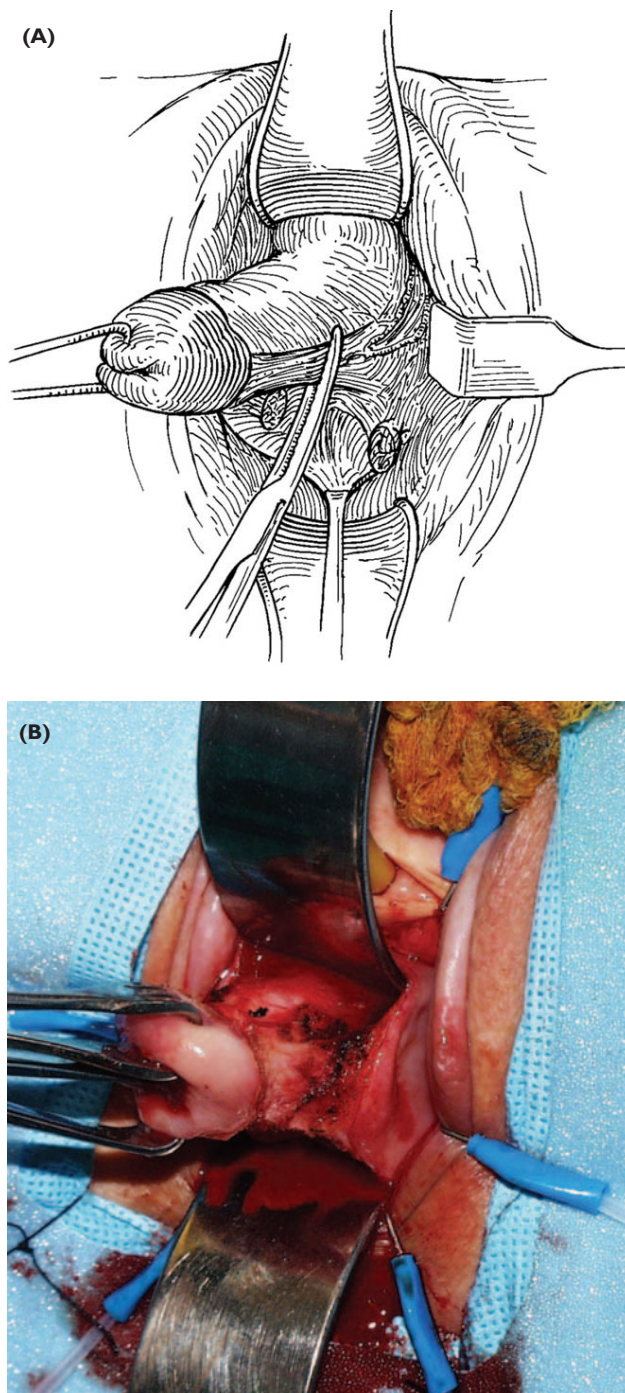


Figure 65.8 Technique of vaginal hysterectomy. Retractors are placed into the vesicouterine space and the posterior cul de sac, exposing the cardinal-uterosacral ligament complexes on each side of the cervix.

using the same technique above and the uterus and cervix are removed (Figure 65.9). Next, elective salpingoophorectomy can be performed followed by the

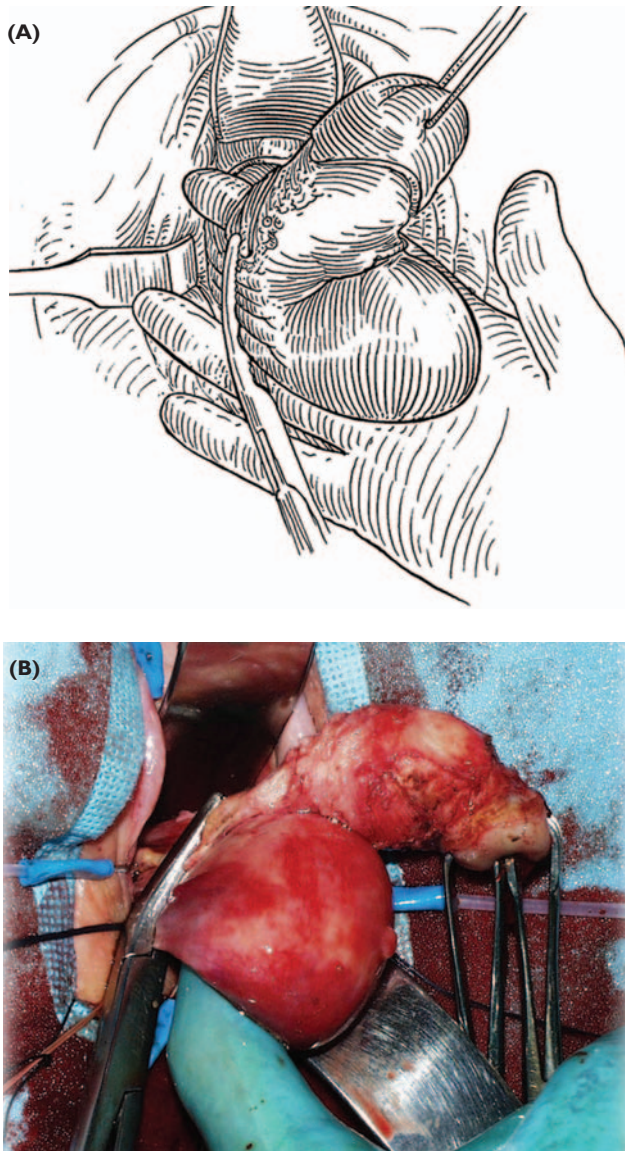


Figure 65.9 Technique of vaginal hysterectomy. The uterine fundus is delivered through the introitus posteriorly, and the broad ligaments are clamped and suture ligated, allowing removal of the specimen.

enterocele repair and vault suspension procedure. These techniques are discussed below in the section on vault suspension.

Uterine sparing techniques

Vaginal approaches

The Manchester procedure The Manchester procedure is currently rarely performed in the US but remains a uterine sparing alternative prolapse repair reserved for patients with cervical elongation who

desire to retain the uterus. The operation consists of amputation of the elongated cervix, followed by suturing of the ligated cardinal ligaments to the anterior cervical remnant. This removes the elongated cervix from the vagina and simultaneously rotates the cervix posteriorly and elevates the uterine corpus anteriorly thereby increasing functional vaginal length.⁵⁴

There appear to be no significant differences in complication rates compared with vaginal hysterectomy, with the exception of cuff abscess formation occurring in 5% of vaginal hysterectomy patients.⁵⁵ However, patients must be counseled that the procedure carries between a 4.3 and 21% prolapse recurrence rate and, also, while technically fertility sparing, may incur higher rates of infertility and pregnancy loss.⁵⁴

Sacrospinous hysteropexy The most commonly utilized transvaginal uterine suspension technique is the transvaginal sacrospinous hysteropexy in which the uterosacral ligaments at the level of their attachment on the posterior aspect of the cervix are sutured to the sacrospinous ligaments either unilaterally or bilaterally thereby resuspending the prolapsed uterus. Early successes with this procedure^{56,57} were confirmed by a subsequent case-control study⁵⁸ and a prospective controlled trial⁵⁹ demonstrating similar objective success rates when compared with vaginal hysterectomy with concurrent sacrospinous suspension. The study by Hefni et al⁵⁹ demonstrated objective success rates of 94–95%, and equivalent vaginal dimensions as assessed by pelvic organ prolapse quantitative (POP-Q) for both sacrospinous hysteropexy and vaginal hysterectomy, but showed higher complication rates with the latter. However, prospective, randomized studies with long-term follow-up are still needed.

While the procedure maintains the option of fertility, the recurrence rates with term pregnancy are reported to be 20–50%, even with delivery by cesarean section.^{57,58} Thus, it seems prudent to simply advise patients to complete child-bearing before undergoing prolapse surgery.

Abdominal/laparoscopic approaches The abdominal sacrohysteropexy is the uterine sparing version of the abdominal sacrocolpopexy. Typically synthetic mesh is used to secure the posterior lower uterine segment to the sacral promontory via an abdominal retroperitoneal approach. A laparoscopic version of the procedure has also been described, and a small series has determined that the procedure is safe with favorable

results.⁶⁰ The overall objective success rates for the open abdominal approach in the recent literature range between 77 and 95%^{61–63} with minimal complications. As for sacrocolpopexy, sacrohysteropexy also carries the same risks of hemorrhage of the presacral veins and bowel obstruction, but also carries the potential risk of hemorrhage from the uterine artery during the cervical fixation. However, to our knowledge, the latter complication has not been reported to date.

While fertility remains possible after the operation,⁶² there are few data on whether the repair is able to tolerate term pregnancy by either the vaginal or cesarean section routes. It should be noted that the studies of this procedure remain relatively small prospective and/or retrospective series, and a large comparative study with hysterectomy and simultaneous sacrocolpopexy is needed.

Additional uterine sparing procedures are reviewed elsewhere⁶⁴ and include transvaginal and abdominal/laparoscopic uterosacral plication, transabdominal pectineal ligament suspension, and transabdominal/laparoscopic round ligament plication/suspension. Additionally, vaginal colpocleisis, which spares the uterus, but does not preserve vaginal length is an option for patients who desire no vaginal sexual function and otherwise cannot tolerate more extensive reconstructive surgery.

Enterocoele repair

An enterocoele is a herniation of the peritoneal contents between the bladder and rectum at the level of the vaginal vault. When this occurs in the setting of concurrent vaginal vault prolapse, it is termed a complex enterocoele.³³ The principles of repair include reduction of the herniated bowel and repair of the defect in the cul de sac by reapproximating the perivesical and prerectal fascia. Restoration of normal vaginal axis and suspension of the vaginal vault should be performed concomitantly when vault prolapse is present.

Abdominal approaches include the Moschowitz and Halban procedures⁶⁵ which can also be performed laparoscopically. The Moschowitz technique utilizes successive purse string sutures proceeding caudad to cephalad to obliterate the cul de sac. The Halban culdoplasty obliterates the cul de sac by approximating the posterior vaginal wall at the level of the cuff with the prerectal fascia.

A variation of the Moschowitz culdoplasty can be performed transvaginally, but more commonly a

modified McCall culdoplasty is employed which has been shown to reduce postoperative enterocele recurrence compared with both the vaginal Moschowitz procedure and the simple peritoneal purse string closure when performed at the time of vaginal hysterectomy.⁶⁶ The McCall culdoplasty utilizes a purse string to grasp the cardinal-uterosacral complexes and posterior peritoneum/prerectal fascia. The purse string is externalized into the vault and simultaneously closes the cul de sac and elevates the posterior vaginal vault. Since the latter simultaneously elevates the vault and attaches it to the cardinal-uterosacral complex, it is commonly employed as a vault suspension procedure at the time of vaginal hysterectomy with good reported success rates.^{66,67} The main criticisms, however, are that the technique utilizes a cardinal-uterosacral complex that is already weakened due to the underlying condition of prolapse. For this reason we perform a culdoplasty accompanied by a vault suspension procedure involving mesh reconstruction of the uterosacral ligaments in cases of vault prolapse.

Vaginal vault suspension

The provision of apical support is a central component to successful repair of vaginal prolapse since anterior and posterior compartment defects accompany loss of apical support in 67% of cases.¹ Unfortunately, there is no current consensus on the optimal approach and technique for suspension of the vaginal apex. Both vaginal and abdominal/laparoscopic approaches have been described. Two important points to consider, regardless of approach, are that the most commonly employed techniques all involve fixation of the vaginal apex to a strong, fixed structure within the pelvis; and a procedure to correct and prevent future development of enteroceles should be performed concurrently. The most common currently utilized techniques are reviewed below. Ultimately, since no firm consensus exists, the technique chosen should reflect the individual circumstances of the case including (1) the need to perform concurrent repair of other compartment defects and/or hysterectomy; (2) the health of the pelvis, especially with regard to the possibility of adhesions; (3) the overall health of the patient especially with regard to tolerance of possible laparotomy, placement in high lithotomy, and duration of anesthesia; (4) the patient's current and desired future degree of vaginal sexual activity; and (5) most importantly, the comfort level and expertise of the surgeon.

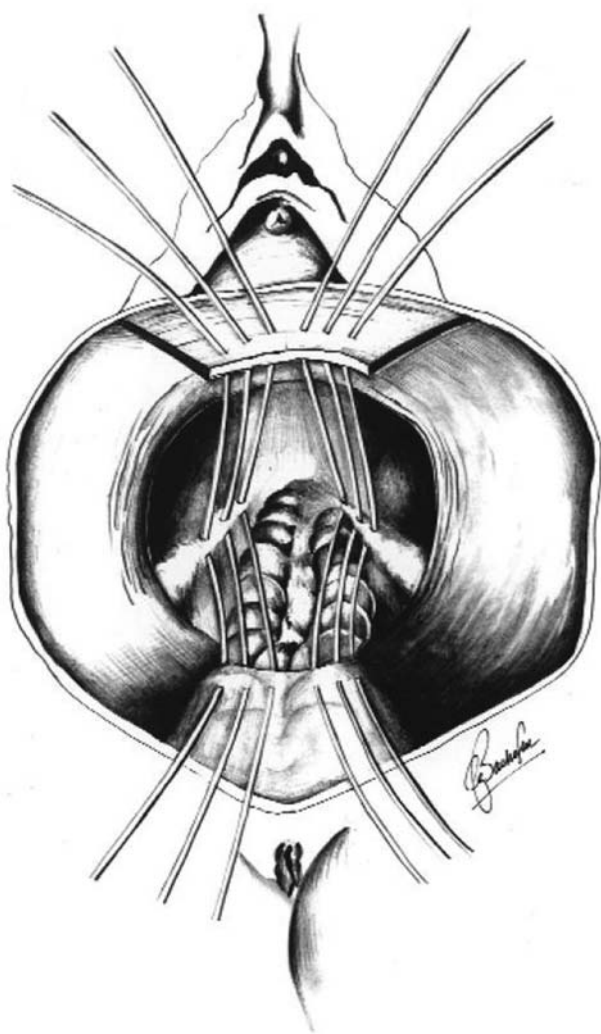


Figure 65.11 Uterosacral ligament suspension. From reference 84, with permission. Reproduced with permission of Dr Claudia Bachofen. All rights reserved.

Vaginal approaches

Sacrospinous ligament fixation The sacrospinous ligament fixation as described by Randall and Nichols⁶⁸ involves a posterior, extraperitoneal vaginal approach into the pararectal space allowing a vault suspension suture to be placed into the sacrospinous ligament within the substance of the coccygeus muscle under direct vision or tactile guidance. Both unilateral and bilateral variations have been described. Large case series report success rates ranging between 90 and 98%.^{69–74}

The main criticism of sacrospinous fixation is that the procedure alters the vaginal axis in such a way that there is a propensity for prolapse recurrence

within the anterior compartment.⁷⁵ A large, retrospective study by Paraiso et al⁷⁰ demonstrated a time-dependent increase in postoperative recurrence of prolapse, most commonly within the anterior compartment (37%). A similar pattern of recurrence after bilateral sacrospinous fixation has been confirmed in a prospective, randomized study.⁷⁶

The primary risks of the procedure are injury to the pudendal neurovascular pedicle, the inferior gluteal neurovascular pedicle, and the sciatic nerve.⁷⁷ Sutures placed too laterally risk injury to the pudendal neurovascular pedicle which typically passes posterior to the ischial spine, but may be present up to 5.5 mm medial to it. The sciatic nerve lies lateral to the ischial spine,⁷⁷ but a misdirected lateral suture could easily grab a portion of the nerve. A superiorly placed suture also risks gluteal artery injury as it passes close to the upper lateral aspect of the sacrospinous ligament.⁷⁷ Thus, the suspension suture must be placed inferomedial to minimize risk of these potential complications. Additionally, careless technique can lead to rectal injury. Despite these risks, serious complications are relatively rare.⁷⁸

Iliococcygeus fascia suspension The iliococcygeus fascia suspension utilizes the same posterior approach as the sacrospinous suspension, but anchors the vault suspension sutures bilaterally to the iliococcygeus muscle and fascia approximately 1 cm caudo-medial to the ipsilateral ischial spine.⁷⁹ The technique offers the theoretical advantage of decreased risk of neurovascular injury compared with sacrospinous colpopexy by placing the suture far from the neurovascular structures that lie in close proximity to the ischial spine,^{80,81} but a case-control study by Maher et al⁸² failed to demonstrate any significant difference in complication rates or success rates in patients undergoing either procedure. Reported success rates are between 53 and 97%.^{80–82} A recent study by Koyama et al⁸³ found excellent durability of the procedure when combined with McCall culdoplasty (8.3% recurrence) compared with McCall culdoplasty alone (33% recurrence).

Uterosacral ligament suspension The uterosacral ligament suspension with fascial reconstruction described by Shull et al⁸⁴ resuspends the vault and repairs an associated enterocele using a series of sutures passing from lateral to medial along the uterosacral ligaments bilaterally and then through the ipsilateral anterior and posterior vaginal cuff.⁸⁴ Tying the sutures suspends the apex to the uterosacral ligaments (Figure 65.11). The procedure can be performed extraperitoneally if no

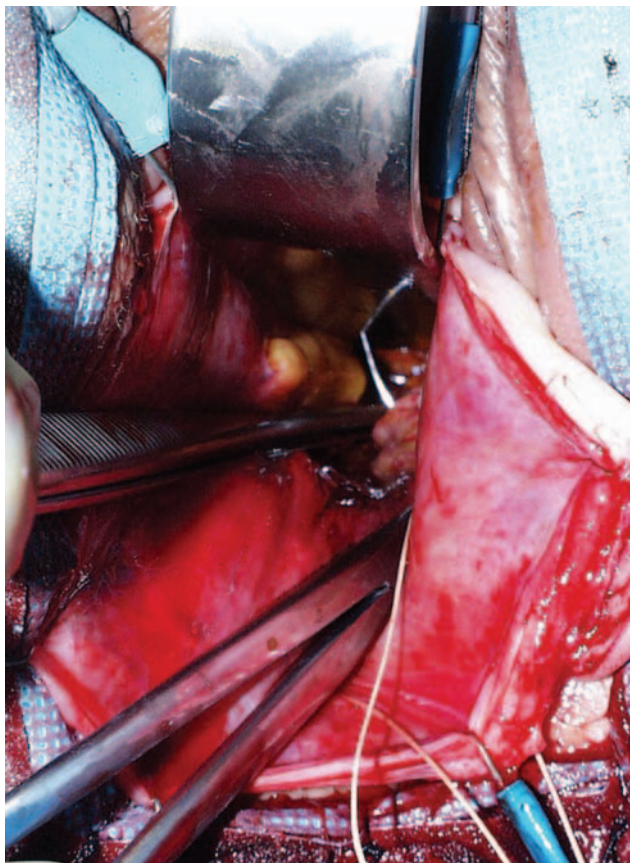


Figure 65.12 Placement of vaginal vault suspension suture into the origin of the uterosacral ligament in the space between the iliococcygeus muscle and the rectum. This suture is passed through one of the arms of the horizontal portion of the 'T' shaped mesh. The same procedure is performed on the contralateral side.

enterocele is present.⁷⁹ Reported success rates for cure of vault prolapse are between 87 and 100%.⁸⁴⁻⁸⁹ More recently, the long-term recurrence rates of the technique were reported to be 15% in any vaginal compartment and 2.5% recurrence in the apex at a mean follow-up of 5 years.⁸⁹

The main risk of the procedure is ligation or kinking of the ureters due to the close proximity of the ureter to the uterosacral ligament, especially in the region of the distal (cervical) portion of the ligament.⁹⁰ For this reason, after tying of the suspension sutures, intraoperative cystoscopy with administration of intravenous indigo carmine to observe the ureteral jets is mandatory. The overall occurrence of this complication is relatively low with reported rates between 1 and 2.4% in large series by experienced pelvic surgeons.^{84,88}

Although evidence shows the uterosacral ligaments to be exceedingly strong in cadaver studies,⁹⁰ another criticism of the technique is that the same weakened

ligaments which presumably contributed to the condition of prolapse are used as the primary basis of the repair. For this reason we choose to perform a modification of the procedure involving closure of the cul de sac and mesh reconstruction of the uterosacral ligaments as described below. The mesh is affixed to the origin of the uterosacral ligament within the cleft between the iliococcygeus and the rectum. This area is distant from the ureter, pudendal neurovascular bundle, and the gluteal vessels, thereby minimizing the risk of injury to all of these structures.

With the patient in high lithotomy position, the enterocele sac is opened after marking the vaginal cuff with marking sutures in posthysterectomy patients or, if hysterectomy has been performed concurrently, the peritoneal cavity is exposed. The bowel is packed and protected with moist laparotomy pads and a 'T' shaped soft prolene mesh is fashioned (arms 4×1 cm, and vertical segment 3×6 cm). Next, a 1-0 Vicryl suture is passed through the vaginal wall into the peritoneal cavity posterolateral to the vaginal cuff. Next, the suture is placed into the origin of the uterosacral ligament complex in the groove between the ileococcygeus muscle and the rectum, lateral and anterior to the sacrum (Figure 65.12). This location minimizes risk to the pudendal neurovascular bundle, gluteal vessels, and the ureter, but the needle must point posteriorly when initially placing the suture in this area to avoid inadvertently catching the ureter as it passes along the anterior leaflet of the uterosacral ligament. This maneuver ensures that only the inferior leaflet of the origin of the uterosacral leaflet is incorporated, thereby minimizing risk of injury to the ureter.

Next, the suspension suture is placed through the ipsilateral arm of the mesh and passed back out into the vaginal apex approximately 1 cm from where it entered. The same maneuver is repeated on the opposite side. Next, two culdoplasty purse string sutures are placed to repair the enterocele. In patients undergoing simultaneous hysterectomy, the purse string includes prerectal fascia, the transverse segment of the mesh, the ligated cardinal-uterosacral complexes, the ligated broad ligaments, and the perivesical fascia. In cases of posthysterectomy prolapse, the ligated broad ligaments are omitted. This maneuver closes the cul de sac and reapproximates the perivesical fascia to the prerectal fascia, thereby repairing the enterocele. It is very important to place the purse string sutures as close to the vaginal cuff as possible to avoid shortening of the vagina once they are tied. Next, any associated cystocele should be repaired and the vault suspension sutures must be tied down prior to excision of excess anterior vaginal

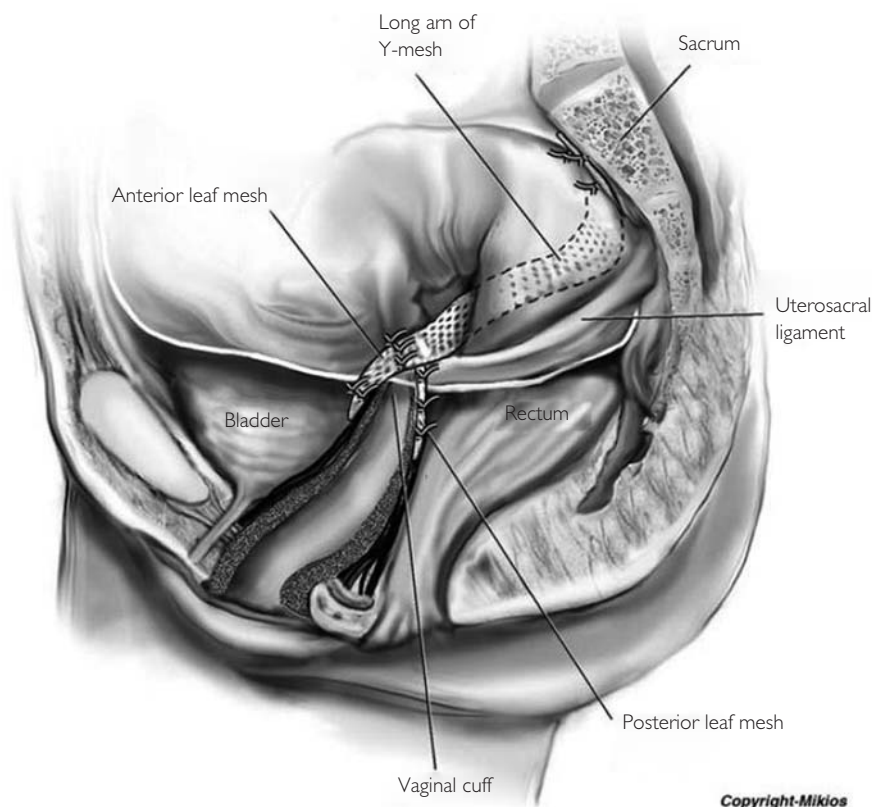


Figure 65.13 Abdominal sacrocolpopexy using mesh. From reference 25, with permission. Reproduced with permission of Dr John Miklos. All rights reserved.

wall and closure of the anterior vaginal wall. The longitudinal segment of the mesh is then utilized to repair any associated rectocele as discussed later in this chapter.

Abdominal and laparoscopic approaches to vaginal vault prolapse

Abdominal sacrocolpopexy The mesh abdominal sacrocolpopexy is a commonly employed abdominal vault suspension procedure (Figure 65.13). Through a midline or Pfannenstiel incision, the bowel is packed superior to the sacral promontory, and the anterior longitudinal ligament overlying the sacral promontory is exposed. The peritoneum overlying the vaginal cuff is dissected away, and a synthetic mesh is sutured to the vaginal cuff. Next, any associated enterocele is suture ligated, followed by a Halban culdoplasty. Finally, the mesh is sutured to the strong anterior longitudinal ligament overlying the sacral promontory while leaving adequate space over the rectum to prevent mesh compression of the rectum.⁹¹

This repair has been criticized because of the creation of an abnormal vaginal axis in which the cuff is directed superiorly toward the sacral promontory instead of the lower sacrum, with a theoretical

increased risk of recurrent prolapse, and also because of the inability to simultaneously place a suburethral sling via the abdominal route. The latter point is especially important given that there is recent evidence suggesting that a concomitant urethral support procedure should be performed at the time of sacrocolpopexy.⁹²

Nonetheless, the technique maintains a functional vagina with favorable apical cure rates ranging between 78 and 100%.⁹³ Because there is evidence that sacrocolpopexy preserves vaginal length somewhat better than sacrospinous fixation,⁹⁴ some authors recommend this approach for younger, sexually active women with apical prolapse to avoid any risk of vaginal shortening.⁹¹ However, when properly performed, both techniques produce an average vaginal length within the normal range.⁹⁴

Aside from the increased pain, ileus, and hospital stay associated with laparotomy, the main risk of abdominal sacrocolpopexy is bleeding from the presacral veins which can be profuse and difficult to control.⁶⁹ The risk of hemorrhage and/or resulting transfusion is reported to be between 0.18 and 17%.⁹³ Comparison with transvaginal sacrospinous fixation demonstrates a significantly higher mean blood loss associated with abdominal sacrocolpopexy.⁶⁹

However, the prospective, randomized study by Benson et al⁷⁶ suggests improved optimal outcome, and lower reoperation rates with the abdominal sacrocolpopexy when compared with transvaginal sacrospinous suspension. The authors concluded the abdominal approach is superior to the vaginal approach. However, this study has been criticized for presenting the authors' impression of 'optimal outcome' instead of the actual objective findings. Additionally, critical review reveals only a 9.5% difference in reoperation rates between the two groups (2% versus 12%), but this occurred at the cost of more serious complications in the sacrocolpopexy group including hemorrhage, obturator nerve injury, enterotomy, sciatica, and wound infections, none of which occurred in the vaginal group (in which the most common complication was urinary tract infection). Additionally, the abdominal approach incurred a longer operative time, and higher cost. A more recent prospective, randomized trial by Maher et al⁹⁵ failed to demonstrate a significant difference in objective cure rates between abdominal sacrocolpopexy and sacrospinous suspension.

Laparoscopic and robotic techniques of abdominal sacrocolpopexy have been described.^{96,97} These techniques appear to be safe and have equivalent success rates when compared with the open technique.^{26,97} The enhanced visualization of the pelvis provided by these techniques also facilitates the dissection necessary to simultaneously repair rectocele, perineal descent, and cystocele by extending the mesh onto the prerectal and perivesical fascia. Additionally, these techniques avoid the morbidity of laparotomy, but incur the learning curve involved in acquiring expertise in laparoscopic and robotic surgical techniques. The merits of the laparoscopic and robotic approaches await randomized, comprehensive comparison with open abdominal and vaginal suspension procedures.

REPAIR OF POSTERIOR COMPARTMENT PROLAPSE

Surgical goals of posterior repair

A defect within the posterior vaginal compartment encompasses four separate defects each of which must be corrected to restore proper vaginal axis, depth and caliber. The four defects include (1) the attenuated rectovaginal fascia within the proximal vagina, approximately 5–7 cm between the vaginal apex and the levator hiatus; (2) separation and widening of the perineal membrane and levator hiatus in the distal

3–4 cm of the vagina; (3) descent of the levator plate; and (4) perineal tear with shortening of perineal body and wide introitus. The deficiency can be in all the components or in the individual ones. Typically there is a combined defect.

In posterior repair there is no correlation between anatomic and functional results. Thus, a successful anatomic restoration does not ensure a successful functional restoration. This situation is fundamentally different from the outcomes of anti-incontinence procedures and makes interpretation of the literature on surgical outcomes of posterior repair difficult since much of the literature focuses on functional outcomes after surgery.

Approaches to posterior repair

The three basic approaches to posterior repair are transanal, transabdominal, and transvaginal. The technique employed usually reflects the surgeon's area of expertise and comfort. Most studies reporting the success and failure rates of posterior repair are small, and there is a lack of standardization of outcomes, particularly with regard to the definition of surgical success. Prospective, randomized studies comparing the outcomes of transvaginal with transanal approaches do not exist. However, two studies comparing the transvaginal and transanal approaches reveal that the transanal approach is associated with lower blood loss, lower narcotic use, and shorter hospital stays.⁹⁸ However, the transvaginal approach proved superior when analyzing both subjective and objective results.⁹⁹

Abdominal approaches

The abdominal approach is indicated after failed vaginal repair, when concomitant abdominal surgery is required, or when the surgeon is unfamiliar with the vaginal approach. This approach for posterior wall defects is usually part of a vault suspension procedure. However, it can be applied to isolated rectocele repairs. Both open and laparoscopic approaches have been described.

Modified abdominal sacrocolpopexy Abdominal sacrocolpopexy is primarily a technique used for vault prolapse and is reviewed earlier in this chapter. However, a modification of the technique has been described to repair concurrent rectoceles transabdominally. The modification involves development of the plane between the vagina and rectum to the level of the perineal body and placement of reinforcing mesh within this space. The goal is to both suspend the perineal body and to reconstruct a strong rectovaginal septum.¹⁰⁰ This

avoids the need to perform a concurrent transvaginal rectocele repair at the time of sacrocolpopexy.

The reported posterior compartment success rates for this procedure range between 43 and 93%.^{101–103} Detachment of the mesh from the perineal body appears to be a significant cause for rectocele recurrence.¹⁰² Due to the mixed success rates, there is currently no consensus on the utility of this type of repair.

Laparoscopic sacrocolpopexy Although there are many reports of laparoscopic vaginal vault repair, few reports focus on the laparoscopic repair of posterior compartment defects. Thornton et al¹⁰⁴ have compared the outcomes of laparoscopic rectocele repair with those of the transanal approach. The authors concluded that the transanal approach was superior due to improved defecatory function in the transanal group. However, this occurred at the expense of higher rates of dyspareunia and postoperative fecal incontinence in the transanal group. Additionally, anatomic outcomes were not assessed in the study.¹⁰⁴

Transvaginal approaches

The four basic transvaginal approaches to posterior compartment repair include levator plication, midline plication of the rectovaginal fascia, site specific repair of the rectovaginal fascia, and our four defect repair (with or without mesh).

Levator plication Levator ani plication involves midline reapproximation of the widened levator hiatus by plicating the puborectalis muscles. While this procedure typically achieves a cosmetic result, the postoperative dyspareunia rates range between 27 and 50%.^{105,106} Moreover, the repair does not address the weakened rectovaginal septum within the proximal vagina.

Midline fascial plication Plication of the rectovaginal fascia within the midline concurrently rebuilds the rectovaginal septum while narrowing the widened vaginal vault. The repair also typically continues with plication of the perineal membrane in the distal vagina. Alternatively, a levator plication may be performed at this level. Excellent anatomic results of the midline fascial repair as high as 92%¹⁰⁷ have been reported with low rates of dyspareunia.¹⁰⁶

Site specific rectovaginal fascia repair The goal of the site specific posterior repair is to repair only the attenuated areas of the rectovaginal septum instead of the entire septum. While the technique has relatively low postoperative dyspareunia rates,¹⁰⁶ a retrospective,

comparative study demonstrates that it carries a higher rate of recurrence as well (44% versus 18%) when compared with midline plication.¹⁰⁸ Additionally, this repair, as it is described in the literature does not address all four components of the posterior compartment.

Transvaginal four defect repair (with or without mesh)

Our repair includes the rectocele repair (repair of the rectovaginal fascia), approximation of the perineal membrane to narrow the levator hiatus, perineal repair, and support of the perineal body to prevent descent. Because of the deficient tissue often present in severe posterior prolapse we use mesh reinforcement for these cases.

With the patient in lithotomy position, a ring retractor with hooks is placed. A deep right-angle retractor is used anteriorly to expose the posterior vaginal wall. Two Allis clamps are placed at the margin of the introitus on the posterior fourchette at the 5 and 7 o'clock positions. A triangular-shaped incision is made in the perineum and the skin is excised exposing the perineal membrane. The posterior fourchette is excised between Allis clamps. Two Allis clamps are applied on the distal posterior vaginal wall. The upper Allis clamp is applied 3–4 cm from the introitus at the level of the levator hiatus. A triangular incision is made from the levator hiatus toward the excised perineal junction (Figure 65.14A and B).

Using scissors, the vaginal wall is dissected laterally, exposing the attenuated prerectal fascia. The vaginal wall is further dissected towards the cuff and a rectangular strip of vaginal tissue is removed. This is approximately 1–2 cm wide and care should be taken to avoid removing too much tissue as this may result in vaginal narrowing. If the rectocele is large, a 'T' shaped piece of soft polypropylene mesh (arms 4 × 1 cm and vertical segment 3 × 6 cm) is constructed and the horizontal arms are affixed to the origin of the sacrouterine ligaments (intraperitoneally if a concurrent enterocele is repaired, and extraperitoneally if there is no enterocele). The vertical segment of the mesh is placed over the prerectal fascia to the level of the perineal membrane.

Using a Heaney or large right-angle retractor, the anterior vaginal wall is retracted upward and the posterior vaginal wall is retracted downward. This maneuver protects the rectum from injury, exposes the pre- and pararectal fascias, and prevents vaginal shortening during the repair. Plication of the pre- and pararectal fascia is performed by using 2-0 slow absorbable suture in running, locking fashion. This fascia is plicated in the

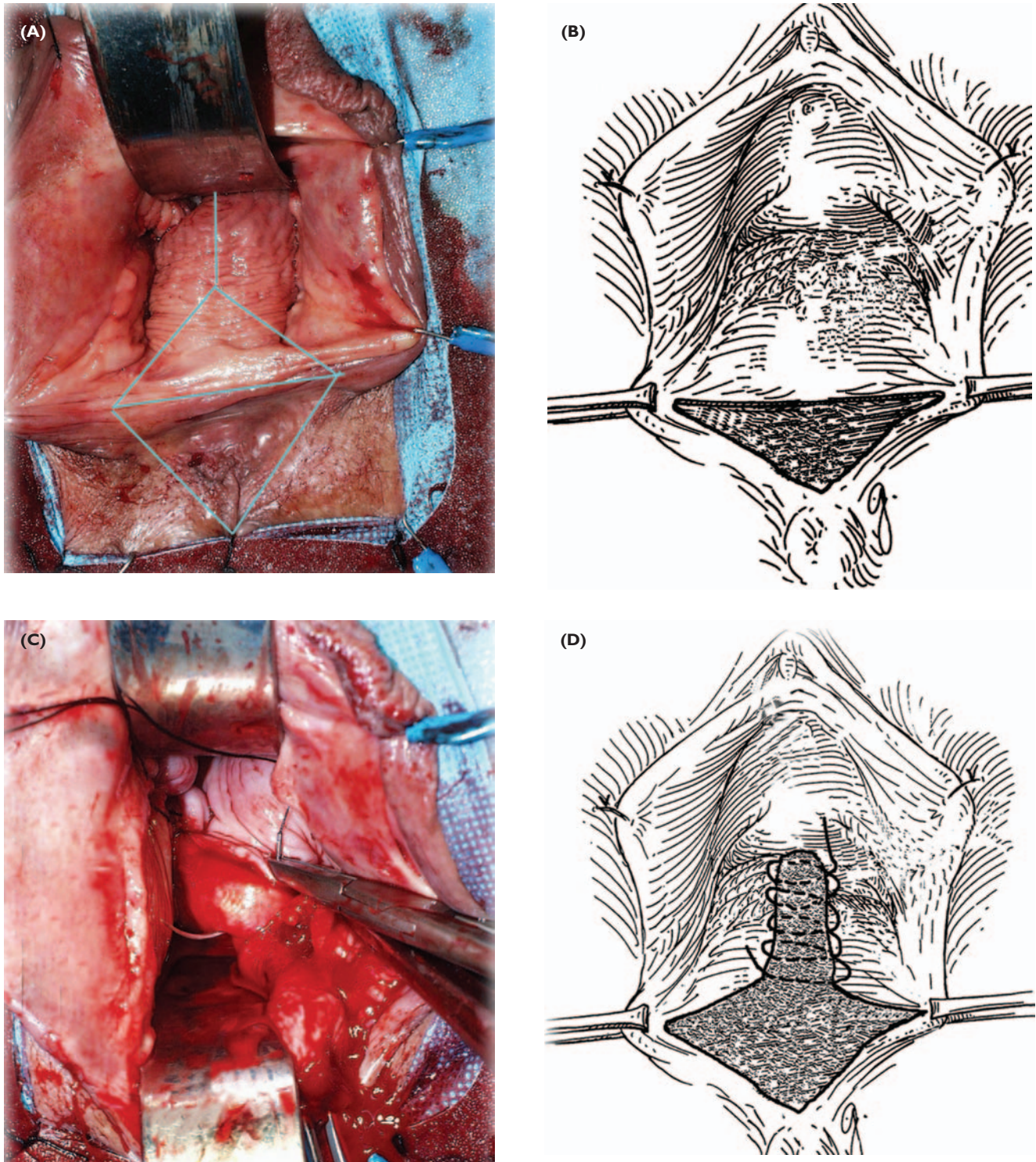


Figure 65.14 The rectocele repair. (A) and (B) The posterior fourchette has been removed and (C) and (D) the pararectal fascia is being plicated in the midline just proximal to the perineal membrane.

midline over the polypropylene mesh (Figure 65.14C and D). Proximally, the uterosacral ligament complex is incorporated if the vault is well suspended and no mesh is used in the repair. This resuspends the prerectal

fascia to the cardinal-uterosacral ligaments and also aids in enterocele prevention. The plication sutures incorporate the edge of vaginal wall and generous amounts of pre- and pararectal fascia.

Suturing is continued distally, taking care to close the pararectal fascia over the polypropylene mesh. This closure is continued to approximately 3–4 cm from the introitus. At this level the two halves of the widened perineal membrane are plicated with 2-0 polyglactin sutures placed in interrupted, figure-of-eight fashion. This maneuver also reapproximates the separated halves of the levator muscle. If mesh is used, this is incorporated into these sutures to further reinforce the perineal membrane and to prevent descent of the perineum by effectively suspending it to the prerectal fascia and the cardinal-uterosacral ligaments.

If the perineum is disrupted, the superficial transverse perineal muscles, external anal sphincter, and bulbocavernosus muscles are approximated using 2-0 slow absorbable horizontal mattress sutures. This completes the perineal body repair. This confers support to the central tendon. The perineal skin is then closed using 3-0 slow absorbable suture. An antibiotic soaked sponge is placed within the vagina and left in overnight.

Transanal approach

The transanal approach is typically utilized by colorectal surgeons. The approach was first described by Marks in 1967.¹⁰⁹ Marks proposed that the rectum was the high-pressure component of the defect. He devised a technique aimed at repairing the attenuated circular and longitudinal layers of the rectum.

The patient is placed in the prone 'jack-knife' position. The anterior rectal mucosa is incised transversely just proximal to the dentate line. Ten centimeters of the circular muscle are sharply separated from the anterior mucosa. Lateral dissection is performed for only half of the circumference of the rectal canal, or 180°. The circular muscle is then plicated to the midline with interrupted non-absorbable sutures. Any excess tissue is excised and the remaining mucosa is repaired using slow absorbable running suture. Follow-up data are primarily focused on defecation patterns.

Long-term outcomes of transanal repair are relatively poor, with recurrence rates approaching 50% in some series.¹¹⁰ Comparative studies demonstrate superior subjective and objective results with the transvaginal approach compared with the transanal approach.⁹⁹ However, when laparoscopic repair is compared with transanal repair, results favor the transanal repair with significantly more patients reporting bowel symptom alleviation and higher patient satisfaction.¹⁰⁴ However, this occurs at the cost of higher rates of postoperative dyspareunia in the transanal group.¹⁰⁴

Repair of perineocele

Perineoceles arise secondary to a laxity of the perineal central tendon,^{111,112} and their true incidence remains unknown. The two anatomic defects noted with perineoceles are convex deformity and descent of the perineum with abdominal straining; and widening of the distance between the posterior vaginal fourchette and the anus.^{111,112} This distance is normally approximately 3–4 cm. In women with prolapse and large perineocele, this distance can increase dramatically to over 8 cm¹¹³ (Figure 65.15A).

The goal of perineocele repair is to reconstruct the perineal body such that distance between the posterior vaginal fourchette and the anus, the perineal body length, is returned to its normal length of approximately 3 cm. We have described a perineal site specific technique for the repair of perineocele in which the perineal musculature anterior to the anal sphincter is reapproximated to the transverse perineal muscles using a series of interrupted horizontal mattress sutures¹¹¹ (Figure 65.15B). This is performed at the end of transvaginal rectocele repair. This technique is reported to repair the anatomic defect and its associated symptoms, including constipation.¹¹¹ There are no long-term data reported on the durability of this repair. Other authors have made efforts to specifically address the perineum and perineal descent in the repair of pelvic floor prolapse by affixing the perineum to the sacrum with synthetic mesh while repairing vaginal vault prolapse.^{100,114} These techniques are applicable to the repair of perineal descent, but do not involve the repair of the widened perineum.

CONCLUSION

There are currently a multitude of techniques employed to repair prolapse within each vaginal compartment. Currently, the evidence suggests that vaginal hysterectomy, when feasible, is the optimal approach for hysterectomy for pelvic organ prolapse. However, selection of the optimal approach for anterior, apical, and posterior repair remains a challenge due to the relative lack of outcomes standardization and high quality randomized, controlled comparative trials within the pelvic reconstructive literature. Thus, current therapy is guided primarily by the experience and comfort level of the surgeon. Ultimately, a detailed knowledge of the relevant pelvic anatomy and the risks, advantages, and disadvantages inherent

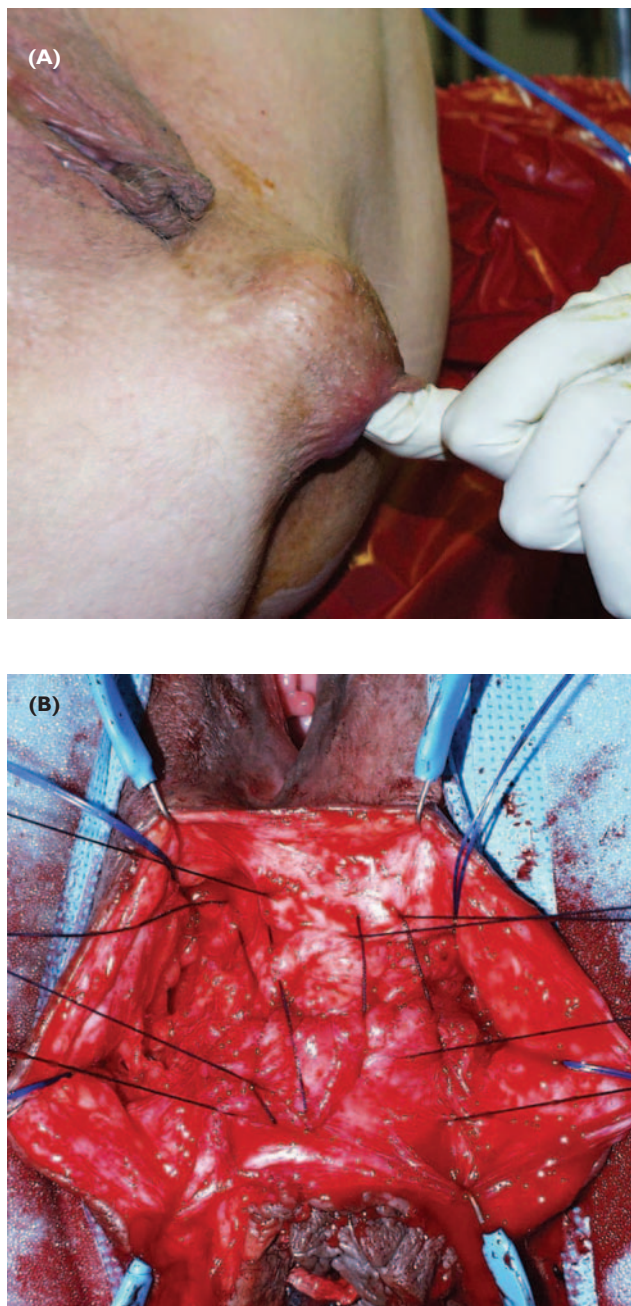


Figure 65.15 (A) Perineocele. (B) Repair of perineocele by suturing of the transverse perineal muscles to the anal sphincter.

in each approach are a requisite for optimal surgical outcomes.

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66 Female genital cosmetic surgery

Rufus Cartwright and Linda Cardozo

The most intimate and unexposed of physical idiosyncrasies, the smallest and most concealed anatomical imperfections, no longer seem worthy of an assertion of privacy, an erotics of modesty . . . [and] are instead willingly exposed, under the pretext of sexual liberation, to the normalising discipline of the social and technocratic gaze.¹

INTRODUCTION

In gynecology, as in the whole of medicine, the balance in the doctor–patient relationship has shifted away from paternalism, towards more patient-oriented decision making. It has become a truism that treatment must be individualized to the patient. We rightly recognize, that when considering surgical intervention, the judgment of the surgeon still takes precedence, but that the patient's own wishes must be taken into account.

While for the most part, this shift in attitudes can only be seen as beneficial, there are settings in which patient-led decision making remains controversial. In obstetrics, arguments continue regarding the ethics of cesarean section on demand, in both the scientific and lay press. In urogynecology it is female genital cosmetic surgery (FGCS) that attracts critical attention. Women's magazines in particular have highlighted these surgical procedures, often viewing them as creating the 'designer vagina'.

While some genital cosmetic operations, such as reduction labioplasty, are relatively well established, it does appear that a range of new procedures is also being performed. Our assessment of the current literature would suggest that the evidence base for many of these procedures varies from minimal to none. In this context there is not even a single case report to support the efficacy or safety of vulvar lipoplasty, augmentation labioplasty, G-spot amplification, or the use of a surgical laser in 'vaginal rejuvenation'. The onus remains on the surgeons who carry out such procedures to audit and publish their results, so that other surgeons can make informed choices about the procedures they offer, and so that patients can make informed choices about the surgery they undergo.

In this chapter we follow the usual classification of FGCS, including procedures for which aesthetic improvement is among the goals of surgery, but excluding procedures performed for developmental sex disorders, and procedures related to female genital mutilation (FGM). There is ongoing debate about the relationship between FGM and FGCS. Aside from the legal and political arguments, a distinction can, however, clearly be made. FGM, where performed is done without consent, upon a minor. For the most part reversal of FGM is performed for functional rather than aesthetic reasons, to allow coitus or parturition.

We separately consider three specific operations that provide a representative overview of the ethical and technical challenges of FGCS. It should be noted though, that these procedures have at best, only level 4 evidence to support their use. In sequence we devote sections to reduction labioplasty, hymenorrhaphy, and the treatment of vaginal laxity with perineorrhaphy.

REDUCTION LABIOPLASTY

Surgical correction of hypertrophic labia minora has been reported from as early as the 16th century. Women request reduction surgery for their labia for two distinct indications: aesthetic dissatisfaction or discomfort. Despite increasing media attention, it remains an uncommon procedure in gynecologic practice, though it is more widely offered by plastic surgeons.

Some cases of enlarged labia minora may be associated with genuine pathology, including chronic irritation, developmental sex disorders, and filariasis, but there has been an erroneous assumption in part of the literature that labia of greater than 4 cm width are necessarily pathologic.

Lloyd et al reported a study in which 50 premenopausal women, undergoing gynecologic surgery unrelated to their external genitalia, consented to have a series of vulval and vaginal measurements taken while under general anesthetic.² They found great variability in all genital measurements. Of relevance to reduction labioplasty, they found the range of labia minora widths to be 7–50 mm (mean 21.8 mm, SD 9.4 mm), and the range of labia minora lengths to be 20–100 mm (mean

60.6mm, SD 17.2mm). None of the participants in their study reported discomfort or embarrassment with their labia, and none had requested surgical 'correction'. The inevitable conclusion is that 'enlarged' labia, of greater than 4 cm in width, are a normal variant.

There has been speculation that embarrassment regarding large labia may arise from comparison with women's genitalia as depicted in pornography and women's magazines, or mistaken beliefs that large labia are indicative of excessive masturbation. Regardless, it is only a minority of women who request labial reduction for purely aesthetic or psychologic reasons. Most women undergoing surgery in fact report discomfort under tight clothes, pain during sports (e.g. horse riding/bicycling), or superficial dyspareunia. Irritation sustained during sports or sex may last for several days, with associated swelling.

Before considering surgery, women should be reassured that large or asymmetric labia are not abnormal, and that they are not usually of clinical significance. While there is good published evidence that most patients are satisfied with the functional and aesthetic outcomes of this procedure, it is unclear whether it relieves associated psychologic morbidity. In our experience a minority of women may experience persistent aesthetic dissatisfaction, and request repeat surgery, despite excellent anatomic correction. Thus women must be carefully counseled, to ensure they have realistic expectations for the procedure.

A variety of techniques have been described, with varying complexities. In our own practice we have had satisfactory outcomes with a simple technique, sometimes described as the 'classic' labioplasty, trimming the free edge of the labium (Figure 66.1A).³ The free edge is injected with 1% lidocaine and epinephrine. Then, the protuberant portion is trimmed in a curved line by eye, using cutting diathermy, much as excess vaginal skin may be trimmed in an anterior colporrhaphy. Hemostasis is achieved with diathermy if necessary, and then the incised free edge is oversewn with interrupted stitches of Monocryl 3-0. The advantages of this technique are that symmetry is easily achieved regardless of the disparity in contour between the two labia, and there is no risk of dehiscence, or flap necrosis. Other authors have reported similar techniques. Some use the application of bilateral clamps down the length of the labia to guide the excision, and improve hemostasis. Others still have suggested that 'W' shaped complementary incisions down the medial and lateral aspect of each labium provide a preferable scar (Figure 66.1B).

Although it has not been our experience, some surgeons have reported dissatisfaction with the above

techniques, on the basis of hypopigmentation along the scar line, and loss of sensitivity. Alternative methods that have been reported include three kinds of wedge resection (Figure 66.1C and 1D),^{4,5} one of which incorporates a Z-plasty (Figure 66.1E).⁶ As is fashionable in FGCS, a small series has also been reported using a surgical laser.⁷ These techniques have in turn been suggested as causing an inadequate or over-tight reduction. Some surgeons now opt to excise a central portion of the labium, leaving the free edge, and its neurovascular supply intact (Figure 66.1F).⁸

There is no evidence to support the use of one of these techniques in preference to the others. It seems plausible, however, that no one method is best suited to all women. We would suggest that each surgeon adopt a procedure with which he or she is comfortable, and apply it flexibly to fit the specific needs of their patients.

HYMENORRHAPHY

Long-standing taboos against women engaging in premarital sex persist in some Mediterranean, Islamic, and East Asian cultures.^{9,10} Before getting married some women may be expected to submit to 'virginity tests' in which a doctor assesses the hymen for evidence of prior sexual intercourse. While one might think such practices were a thing of the past, even Princess Diana underwent a virginity test, before marrying Prince Charles. More degrading still, is that on the morning after the wedding, the marital bed sheets may be inspected for signs of blood, as evidence that the bride has been 'deflowered'. Women who fail either of these tests may be subject to ostracism or violent reprisals, including murder.

Despite the fact that many women do not bleed on first intercourse, and that hymenal tears can arise without prior intercourse, this remains a pressing issue for some young women wishing to get married. There is clearly an ethical dilemma when a gynecologist is asked to reconstruct the hymen, to give the appearance of virginity. It has been argued that doctors should not co-operate in this deceit. It is also evident that by acquiescing to perform the surgery, the doctor is perpetuating misogynist myths about virginity.

Although the procedure is not technically challenging, and has no apparent complications, it should still be undertaken with caution. The surgeon must observe local laws, and be sensitive to their local cultural milieu. In our own practice we take an entirely pragmatic view. If after counseling the woman requesting surgery still considers that it is in her best interest to undergo hymenorrhaphy, we respect that decision. However, given the lack of

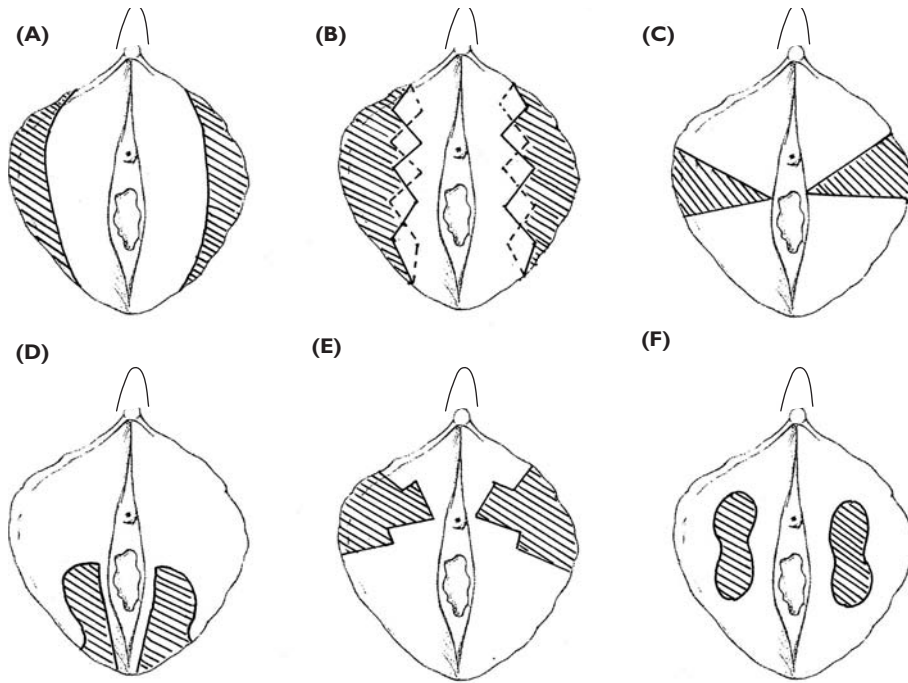


Figure 66.1 Different techniques for labial reduction. Shaded area marks areas to be excised. (A) 'Classic' labioplasty. (B) Complementary 'W' incisions. (C) Medial wedge resection. (D) Posterior wedge resection. (E) Wedge resection with Z-plasty. (F) Central de-epithelializing reduction.

evidence, we make no guarantee that the reconstructed hymen will look like that of a virgin, nor that bleeding will necessarily ensue following sexual penetration.

Some sources report that the procedure should be performed in the days immediately before the wedding. The free borders of the hymenal remnants or hymenal tear are incised. Then the remnants, or edges of the tear, are approximated using either a purse string or interrupted sutures of Vicryl 3.0. This aims to achieve at least partial occlusion of the introitus. In countries where catgut sutures are still available, these may be used in preference. When insufficient hymenal remnants are available to make a satisfactory membrane, then a small flap of vaginal skin can be lifted from the posterior vaginal wall, and approximated to the anterior wall, as a band across the hymenal ring.

The secretive nature of the surgery means it may be undesirable for the women to attend follow-up. However, in one reported series of 20 women, ten were followed up after the wedding night, all reporting a satisfactory outcome.¹¹

PERINEORRHAPHY FOR VAGINAL LAXITY

Vaginal laxity, despite the absence of objective prolapse, is a common complaint amongst parous women. Related symptoms include pelvic discomfort, inability to retain tampons, vaginal wind, and entrapment of

bathwater. The most common specific symptom is reduced sexual sensation. It is not clear, however, that laxity is directly related to sexual dysfunction.¹² Repeated studies have found that there is no correlation between severity of objective pelvic organ prolapse and degree of sexual dysfunction. Some evidence does, however, suggest that the partners of men with erectile dysfunction are more likely to complain of vaginal laxity.

Even in the absence of prolapse, it is evident that there is a wide variation in normal vaginal dimensions in asymptomatic women. A study by Pendergrass et al, taking casts of the vagina from 39 women, using dental putty, demonstrated that the introitus may vary from 2.39 to 6.45 cm in width.¹³ Although the narrower end of the range was occupied by nulliparous women alone, there was no association between parity and width.

Parous women are at greater risk of all varieties of sexual dysfunction in the immediate postnatal period. However, by 6 months there are no observed differences between women who deliver vaginally, and those delivered by elective cesarean.¹⁴ These results would suggest that neither the absolute introital width, nor a change in width associated with vaginal delivery, have a simple relationship with sexual function.

There is very limited evidence that surgical repair improves any of the symptoms of laxity. Thus, we would always recommend an initial multidisciplinary conservative approach. It is clear that postnatal depression and continued breast-feeding are risk factors for sexual dysfunction, owing to both low libido and dyspareunia, and

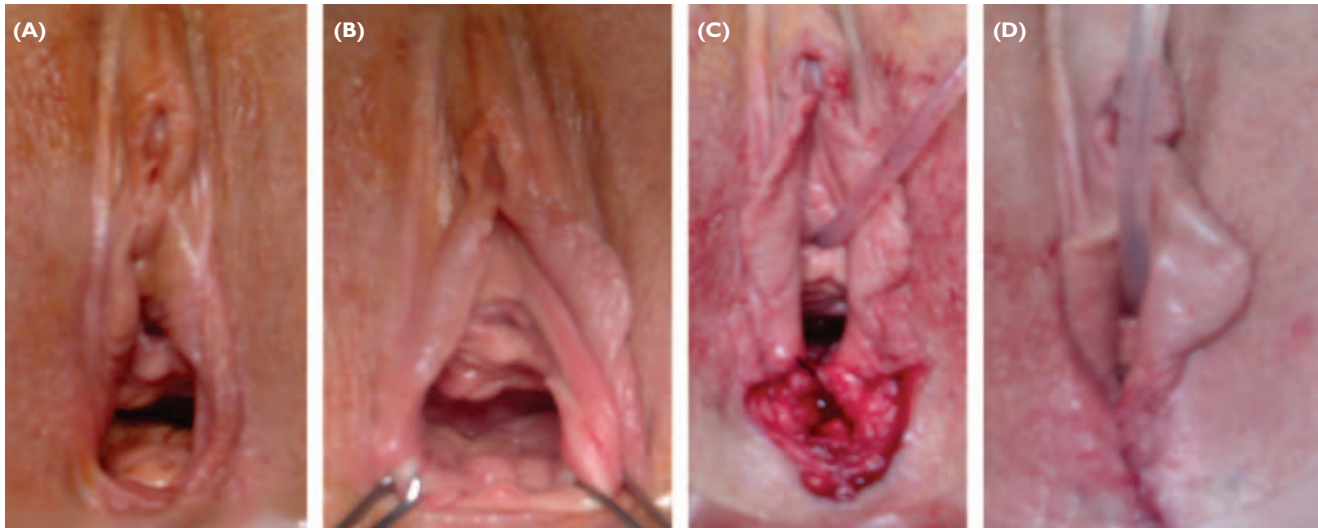


Figure 66.2 Perineorrhaphy. (A) With legs abducted the perineum is deficient, with a gaping introitus. (B) The deficient perineum is grasped bilaterally to mark the margins of the incision. (C) The perineal skin is excised to remove the scarred tissue and the perineal body is plicated. (D) The vaginal wall and perineal skin are closed, as in repair of an obstetric perineal tear.

thus especially for these women, a conservative approach is mandatory. Topical vaginal estrogens are helpful, both for breast-feeding women and perimenopausal or menopausal women. In combination with this, women should undertake a course of supervised pelvic floor muscle training. Where sexual function is of a more global nature, than specific reduced sensation, referral to psychosexual counseling services is also indicated.

If symptoms of laxity persist despite these measures, then surgical intervention can be considered. In some centers, posterior colporrhaphy for 'vaginal rejuvenation' may be offered, even when posterior wall prolapse is not evident. Given that posterior compartment vaginal surgery can cause bowel symptoms and dyspareunia, we recommend that surgery be limited to perineorrhaphy, and then only if the perineum is deficient (Figure 66.2).

It is extremely important not to overestimate the degree of laxity when the patient is under general anesthesia. Before beginning the dissection, two Littlewoods clamps should be placed at the margins of the proposed incision, and then approximated, to check that the resulting introitus is adequate for penetrative sexual intercourse. Following this area of the posterior fourchette is injected with 1% lidocaine and epinephrine, both for hemostasis and to assist in finding the correct tissue planes. The deficient skin of the perineum is then incised, in either an inverted triangle or shallow diamond shape, with two of the apices at the two Littlewoods. The assistant then lifts the posterior corner of this flap under tension, and using scissors the piece can be dissected out intact. Particularly when there is scarring from a previous perineal tear, bleeding may ensue.

From this point, the surgeon proceeds as for an obstetric perineal tear. Deep sutures beyond the margins of the incision are used to buttress the deficient perineal body. Some authors have advocated the use of delayed absorbable sutures such as PDS. In our experience knots of such suture may be palpable under the vaginal skin for many months, causing unnecessary dyspareunia. Rapidly absorbable sutures provide adequate support. Once sufficient bulk is created within the perineal body, the vaginal wall and perineal skin can be closed with subcuticular sutures. Great care must be taken at the mucocutaneous border not to create a thin skin bridge, which again may lead to dyspareunia.

As for a prolapse repair, patients should use laxatives to avoid becoming constipated in the immediate postoperative period. They should also desist from heavy lifting or intercourse for a period of 6 weeks.

There are few, if any reported studies that assess the outcome of perineorrhaphy alone with regard to vaginal laxity. In our own unit, 5-year follow-up of 80 women having combined posterior colporrhaphy and perineorrhaphy for symptomatic prolapse, found that the incidence of symptomatic vaginal laxity had significantly decreased from 25 to 8%.¹⁵

CONCLUSIONS

Interest in FGCS has outstripped high quality evidence of its efficacy and safety. This makes it especially difficult to advise women of the risks and benefits. For the newer procedures that have not yet

been adequately reported, even a prospective cohort study would be of great benefit. For all gynecologic procedures that are requested primarily for aesthetic, rather than medical reasons, research is needed focusing on quality of life, sexual function, and patient-centered outcomes. In the absence of clear evidence the surgeon must be guided by ethical standards, personal experience, and the specific needs of their patients.

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67 Neovaginas for agenesis

Melissa C Davies and Sarah M Creighton

INTRODUCTION

Vaginal agenesis is a feature of many of the disorders of sex development (DSD). The commonest conditions in which vaginal agenesis occurs are Rokitansky syndrome and androgen insensitivity syndrome. In both conditions there is a blind ending vagina of variable length and an absent uterus. At present there are no treatments to allow menstruation or to enable the woman to carry a pregnancy. Current treatments focus on psychologic support and creation of a vagina to allow penetrative sexual intercourse.

VAGINAL DEVELOPMENT

The proximal two-thirds of the vagina develops in fetal life from the paired Müllerian ducts. In a fetus with XX chromosomes, the absence of antiMüllerian hormone (AMH) allows the Müllerian ducts to grow in a caudal and medial direction and fuse in the midline. These ducts form bilateral Fallopian tubes and midline fusion of these structures produces the uterus, cervix, and upper vagina. The rudimentary distal vagina fuses with the posterior urethra at week 7 to form the urogenital sinus. The vagina then develops from a combination of the Müllerian tubercles and the urogenital sinus. Cells proliferate from the upper portion of the urogenital sinus to form structures called the sinovaginal bulbs. These fuse to form the vaginal plate which extends from the Müllerian ducts to the urogenital sinus. This plate begins to canalize, starting at the hymen and proceeds upwards to the cervix.

Vaginal agenesis in individuals with a functional testis such as those with androgen insensitivity syndrome is explained by testicular production of AMH. However, vaginal agenesis in those with XX chromosomes and no testicular function such as in Rokitansky syndrome is not explained. Hormonal, genetic, and environmental factors have been explored but the etiology as yet remains unknown.

THE NORMAL VAGINA

There are few descriptions of normal female genitalia in the medical literature. However, available studies



Figure 67.1 Femmax™ vaginal dilators (Medical Devices Technology, International Ltd., Wolverhampton, UK). Reproduced with permission from Sarah Creighton and Melissa Davies.

demonstrate a wide variation in vaginal size with mean length from 6.5 to 12.5 cm.¹ It is also clear that sexual function may not be related to absolute vaginal length as measured in a clinical setting as this does not take into account changes in dimensions which may occur during arousal and penetrative intercourse.² This must be considered when reporting outcome data from vaginal reconstruction.

CREATION OF A NEOVAGINA

Dilatation

The use of vaginal molds of increasing width and length to successfully create a neovagina was described in the 1930s. Since then vaginal dilatation has become more popular as a first line treatment for vaginal agenesis. There are several dilator products available on the market all of which are used in a similar way (Figure 67.1). The patient is asked to press the smallest dilator onto the vaginal dimple for 30 minutes once or twice each day. When the smallest dilator can be inserted its full length, she then moves to the next size dilator which is both longer and wider. It can take several months before the patient can achieve a vagina large enough for penetration.

Most reports of outcome have been retrospective and have reported on changes in anatomic length

rather than improvement in sexual function. Reported success rates vary from 40 to 100% and there are concerns that compliance and patient satisfaction is generally low. Outcomes are related to compliance and in the past dilators have been prescribed haphazardly and without on-going support. Although ostensibly dilator therapy has low associated morbidity and risk, it has been shown that dilators can also cause significant problems for patients.³ Dilatation therapy can be painful and can also act as a constant reminder of abnormality. It is important therefore that the dilator program is supported by specialist nursing and/or counseling input.

It is also not clear how 'success' is reported in this treatment context. Anatomic success does not guarantee success in sexual function following vaginal reconstructive technique, be it surgical or passive dilatation technique. Female sexual function and dysfunction is based on not only biologic but also psychosocial components. Whilst changes to vaginal volume judged sufficient for coitus certainly occur, it is not known to what extent these changes lead to an improvement in sexual confidence or experience.

Surgical reconstruction

Some women are unable to create a vagina with dilatation alone despite psychologic support. In these women surgical construction of a neovagina is usually the next step. There are many hundreds of surgical procedures for vaginoplasty described in the literature but few have any associated long-term outcome data. The most commonly used procedures traditionally have been creation of a neovaginal space and lining it with either a split-thickness skin graft (the McIndoe-Reed procedure) or a section of intestine. Both are major procedures with significant risks and complications. More recently both the Vecchietti and DavydovTM (Medical Devices Technology International Ltd.) procedures have been modified to allow a laparoscopic approach with the benefits of reduced morbidity and a speedier recovery.⁴

McIndoe-Reed vaginoplasty (Abbe-McIndoe-Reed)

The McIndoe (Abbe-McIndoe-Reed) technique is one of the most commonly described vaginoplasty techniques in the literature. It does not require abdominal surgery and is of a relatively low initial morbidity. A potential neovaginal space is created by blunt dissection of the space made between the rectum and the bladder. A split-thickness skin graft is then taken from the thigh, buttock, or abdomen and is mounted on a mold and left in the neovaginal space for 7 days. The

graft will then epithelialize, lining the neovaginal space. The patient, however, has to continue to maintain her neovagina by regular sexual intercourse or dilator use following the procedure.

A major disadvantage of the McIndoe technique is the formation of visible scars at the origin of the skin graft site as this is usually unacceptable to young women. In addition failure to comply with follow-up dilator treatment can result in vaginal stenosis. Stenosis can lead to painful intercourse or no intercourse at all. Satisfactory long-term results have, however, been reported for the McIndoe operation with 81–100% sexually active after the procedure.⁵ There is, however, scanty information in the literature on sexual function or sexual pleasure in this group and the incidence of contracture is high.⁶ There have been several case reports of squamous cell carcinoma developing in the vaginal graft. It is likely that the increasing use of vaginal dilatation as a first line treatment and the introduction of the Vecchietti and Davydov procedures will mean there is little room for the McIndoe-Reed procedure in modern vaginal reconstruction.

Intestinal vaginoplasty

Intestinal vaginoplasty is performed by removing a segment of bowel approximately 10–12 cm in length with its vascular pedicle still intact. This segment is transposed into the pelvis creating a neovagina and the proximal end closed. The main advantage of this procedure is the avoidance of postoperative vaginal dilatation. Other advantages include adequate vaginal length, natural lubrication, early coitus, and lack of shrinkage. The procedure is usually performed via a laparotomy although the laparoscopic approach has been reported. It carries with it all the recognized complications of major abdominal surgery and great surgical expertise is required. Symptomatic diversion colitis has been reported postoperatively and can lead to heavy vaginal discharge with bleeding.⁷ Persistent foul smelling discharge can affect a patient's self-esteem and confidence. In some cases this will respond to treatment by vaginal irrigation using short chain fatty acids and steroid enemas. Prolapse of the sigmoid neovagina can also occur. In rare cases adenocarcinoma has been reported in the intestinal vagina. Although these complications are uncommon, treatment is difficult and can lead to removal of the entire neovagina. Satisfactory sexual function outcomes have been reported.⁸ However, this is major surgery with high associated morbidity. Intestinal vaginoplasty should be reserved for those women who have failed previous vaginal reconstruction or have other associated complex bowel and urinary anomalies where dilatation and less



Figure 67.2 Traction device for Vecchietti procedure (Karl-Storz-Endoskope, Tuttlingen, Germany). Reproduced with permission from Sarah Creighton and Melissa Davies.

invasive procedures are not possible. It should not be used as a first line treatment for vaginal agenesis.

Vecchietti procedure

The Vecchietti procedure allows creation of a neovagina by passive traction rather than dilatation. An acrylic 'olive' with attached tension threads is placed at the vaginal dimple. The threads are passed under laparoscopic control from the vaginal dimple through the abdominal cavity and then to a traction device on the abdominal wall (Figure 67.2). The tension threads are tightened daily, stretching the vagina approximately 1 cm each day for a week. The procedure can be painful. After 1 week the threads, olive, and traction device are removed and the patient is asked to restart vaginal dilatation or attempt sexual intercourse to maintain vaginal length.

This procedure requires elasticity of the vaginal skin. It is thus not suitable for women with perineal or vaginal scarring from previous failed surgical reconstruction. However, early results are encouraging with patients reporting adequate vaginal lubrication and normal sexual pleasure.⁹

Davydov technique

The Davydov procedure is also performed laparoscopically. A perineal incision is made first to create a neovaginal space. Then peritoneum from the pelvic side walls and the pouch of Douglas is freed and directed down towards the vaginal incision to line the side walls of the vagina (Figure 67.3). The top of the vagina is created by suturing a vaginal 'roof' of large bowel and

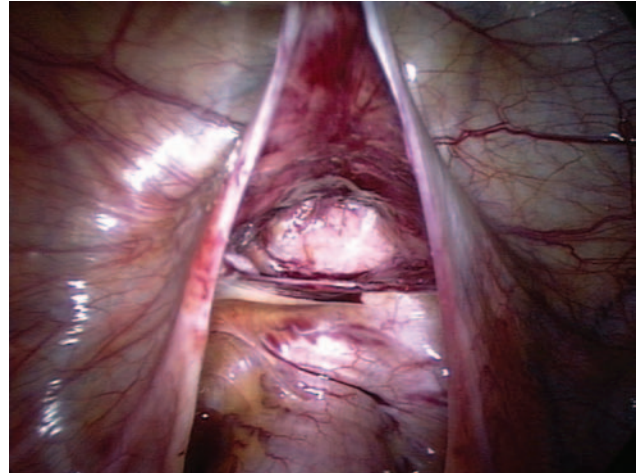


Figure 67.3 Laparoscopic Davydov procedure. A cuff of peritoneum is freed from the pelvic side wall and used to line the sides of the neovagina. Reproduced with permission from Sarah Creighton and Melissa Davies.

peritoneum. A soft vaginal stent is inserted and remains in place for 1 week, after which time it is removed and the patient asked to dilate or attempt intercourse to maintain vaginal patency. This procedure is more suitable for those women with perineal scarring as the vaginal skin is not required to stretch. Good short-term anatomic and functional results have been reported.¹⁰

CONCLUSION

The impact of vaginal agenesis in a young woman can be overwhelming. The loss of fertility can be devastating as is the realization that intrusive, time-consuming, and often complex vaginal treatment is required to achieve coitus.

Given these factors, it is essential that sound emotional and psychosexual support is planned alongside expert medical care. Vaginal dilatation treatment has a low morbidity and should be the first choice of treatment for those women with vaginal agenesis who have not undergone previous genital surgery. If dilatation therapy is not successful, surgery will be required. Both the Vecchietti and Davydov procedures produce good short-term results, although there are as yet scanty data on long-term outcomes. Surgical morbidity with the Davydov procedure is higher and it is more appropriate for those women with genital scarring from previous surgery. The McIndoe-Reed procedure is performed less frequently nowadays due to a high degree of postoperative stenosis. Intestinal vaginoplasty provides a good capacity vagina with natural lubrication. However, morbidity from this procedure is high and associated

complications can be difficult to treat. Because of this, the procedure should be reserved for the small number of complex cases where both self dilatation and less invasive procedures have failed or where there are other major anomalies of the lower genitourinary tract.

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68 Urethral diverticula

Sandip P Vasavada

INTRODUCTION

A urethral diverticulum remains one of the most elusive diagnoses to make in the female patient with voiding dysfunction. The standard evaluation of a suspected urethral diverticulum has matured to a single radiographic study of choice in combination with a high index of suspicion and certain patient examination characteristics that, while easy to overlook, can be realized if attention is appropriately focused.

ETIOLOGY

In most cases, a urethral diverticulum results from repeated infection and obstruction of the periurethral glands. It is widely believed that a diverticulum develops after an initial infectious insult whereby the fluids created within an obstructed periurethral gland cannot drain to the mature and form the diverticulum. The resulting draining abscess cavity is eventually epithelialized, and a urethral diverticulum is formed. Other less common causes of urethral diverticula involve congenital and post-traumatic factors, including, potentially, periurethral injection therapy.

DIAGNOSIS

The classic triad of the 'three Ds' of dyspareunia, dysuria, and postmicturition dribbling is highly suggestive of a urethral diverticulum. While many patients do not present with this classic history, one should realize that a diverticulum may present with the more common symptoms of urinary urgency, frequency, and sometimes hematuria. Additionally, the diverticulum may be complicated by infection, stones, bladder outlet obstruction, and, rarely, malignancy. In general, one should entertain the possibility of a urethral diverticulum in any case of persistent lower urinary tract symptoms unresponsive to therapy.

On physical examination, the urethra may be tender, and there is often a palpable suburethral mass. Manual compression may cause the drainage of purulent material or urine from the external meatus. In rare instances, the patient may present with signs of sepsis

and acute inflammation from a tense, infected diverticulum. Significant manual compression should be avoided and more definitive therapy should be planned.

The presence of urethral hypermobility and stress incontinence should be documented during the initial visit. Q-tip testing and/or provocative testing with a bedside cystometrogram and subsequent Valsalva maneuvers may confirm the presence or absence of leakage. One should be careful to make sure of the diagnosis of stress incontinence in this population as the diverticulum itself may cause dribbling and one should directly visualize the leakage associated with the physical exertion, Valsalva, or cough to ensure that this is the case.

RADIOGRAPHIC EVALUATION

Traditional evaluation and confirmation of the presence of a diverticulum often involved both voiding cystourethrography (VCUG) and positive pressure urethrography (PPUG) with a double balloon catheter. While these studies are specific in defining the location, size, and number of diverticula their sensitivity is questionable. More recently, magnetic resonance imaging (MRI) has proved to have a higher sensitivity in detecting urethral diverticula when compared with positive pressure urethrography (Figure 68.1). This study not only gives multiplanar views and anatomy of the diverticulum but also aids extensively in preoperative surgical planning. Currently, it is considered the anatomic study of choice for a patient with a suspected urethral diverticulum.

TREATMENT

Many patients who do not have significant symptoms from the diverticulum may be followed and treated with conservative measures including antibiotics and anticholinergics. In general, however, most patients desire definitive repair. There exist three surgical options for urethral diverticulum repair: transurethral incision of the diverticula communication, transforming a narrow-mouthed into a wide-mouthed diverticulum; marsupialization of the diverticula sac into the vagina



Figure 68.1 Axial MRI view of the pelvis with a prominent diverticulum on T2 weighted sequence with lateral extensions. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

by incision of the urethrovaginal septum; and excision of the diverticulum. In acute sepsis situations, the diverticulum may also be transvaginally drained and fixed at a later time.

OPERATIVE PROCEDURE

At our institution complete excision of the diverticulum is performed if at all possible. After the patient is prepped and draped a 14–16 Fr silicone urethral Foley catheter is inserted and the bladder is filled with 200 ml of normal saline (Figure 68.2). A suprapubic tube is then placed with assistance from a Lowsley retractor in cases of extensive urethral diverticulum or in those who one suspects of being at risk for some prolonged voiding dysfunction or complex repair. The urethral Foley catheter is replaced and then a ring retractor and weighted vaginal speculum are used for retraction. A marking pen is used to outline an inverted 'U' incision up to the distal aspect of the urethra just proximal to the urethral meatus.

POSTOPERATIVE CARE

Patients are typically discharged either the same day or within 23 hours with both the urethral Foley catheter and suprapubic tubes to gravity drainage. Patients are treated with oral antibiotics for 2 weeks after surgery.

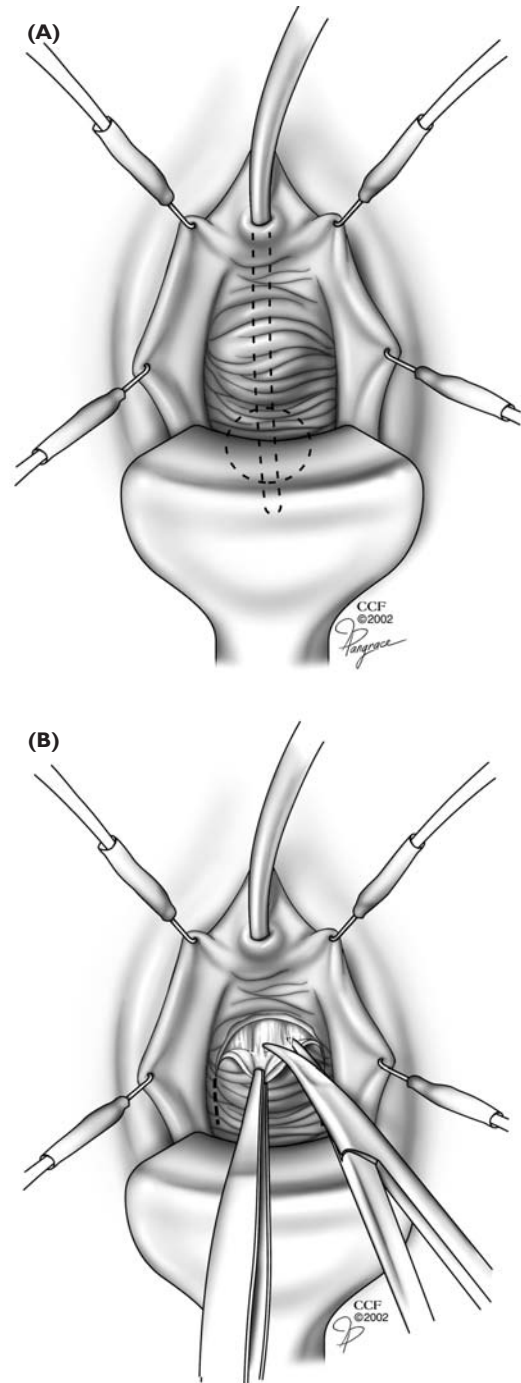


Figure 68.2 (A) Initially, both urethral and suprapubic catheters are placed to ensure maximum postoperative drainage. A 14–16 Fr urethral Foley catheter is inserted to facilitate identification of the urethral wall during the subsequent dissection. Normal saline or lidocaine with epinephrine solution is administered just beneath the vaginal wall to create a plane for dissection. (B) An inverted 'U' incision is created in the anterior vaginal wall with the tip of the 'U' just proximal to the urethral meatus. The vaginal wall flap is dissected posteriorly thus exposing the periurethral fascia. It is important not to enter the fascia or the diverticulum at this point so as to facilitate later dissection and reconstruction. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

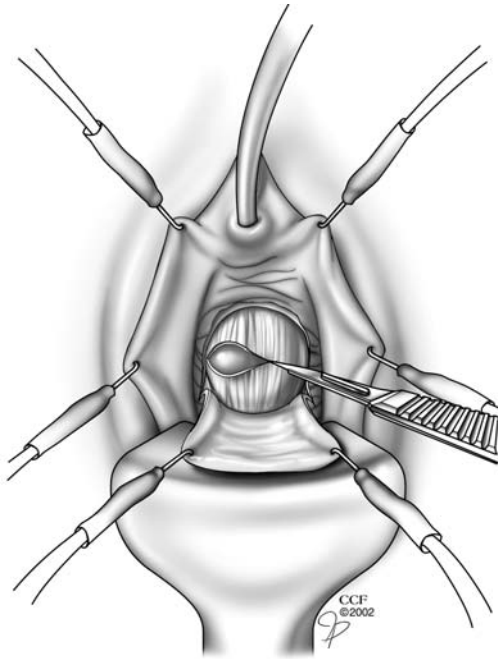


Figure 68.3 Exposed periurethral fascia flaps are created above and below thereby exposing the diverticulum only. The periurethral fascia is then incised in a transverse direction over the diverticulum. This layer may be quite thin and again care must be taken to avoid entry into the diverticulum. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

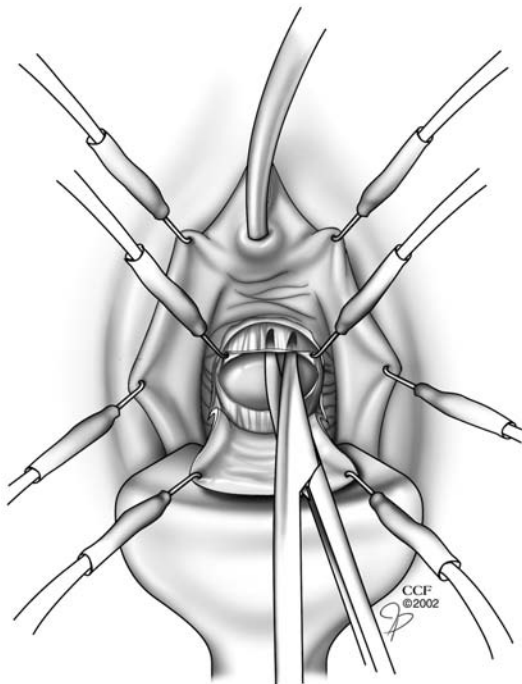


Figure 68.4 The superior and inferior flaps are created thus leaving only the submucosal layer of the urethral wall and the diverticula sac. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

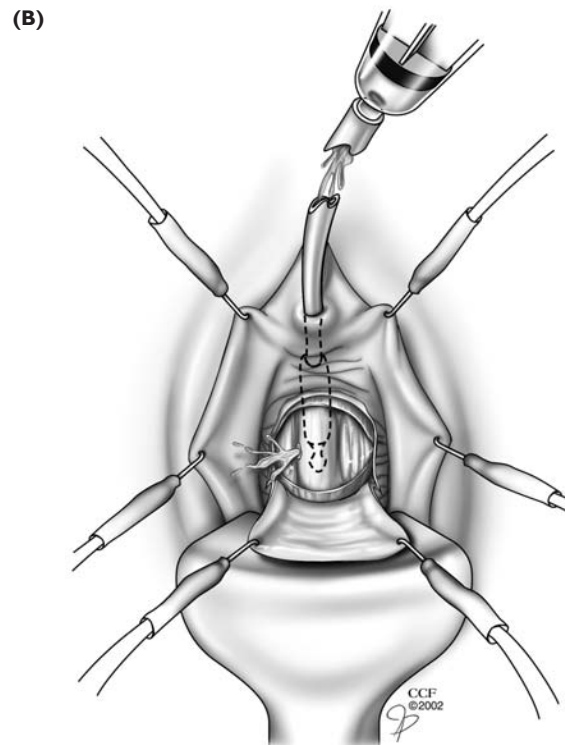
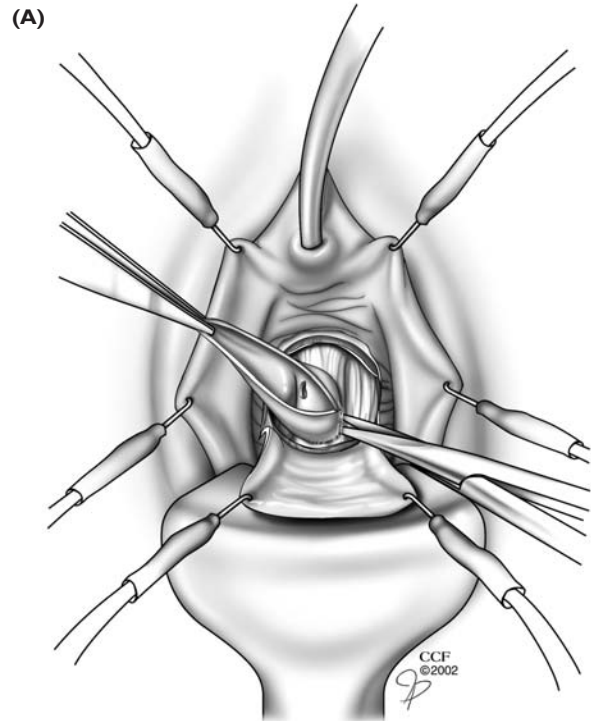


Figure 68.5 (A) The diverticula sac is sharply freed from the surrounding structures and the communication and neck of the diverticulum is then excised flush with the wall of the urethra. The urethral wall is reconstructed using longitudinal closure of the urethral defect with a 3-0 absorbable suture. This must be closed in a watertight fashion without any tension. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

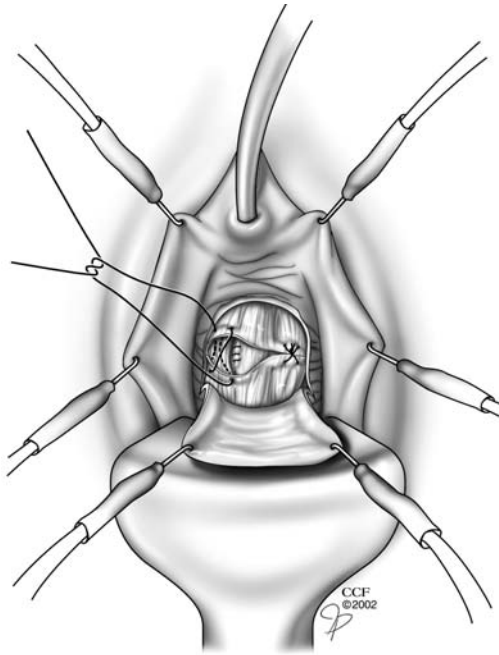


Figure 68.6 The periurethral fascia is trimmed back to healthy tissue edges and closed horizontally with an absorbable 3-0 suture. This layer of closure is perpendicular to the urethral closure to avoid overlapping suture lines. Additionally, there should be no dead space around the closure for fluid accumulation so as to prevent fistula formation. A Martius flap may be placed at this time in complex reconstructions or reoperations. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

Anticholinergic therapy is begun in the immediate postoperative period to prevent bladder spasms. A voiding cystourethrogram is performed 2 weeks postoperatively to rule out extravasation. If a small amount of extravasation is present, the suprapubic tube alone is allowed to remain in place and to gravity drainage while the urethral Foley catheter is removed. A repeat study can be performed in 1 week to demonstrate resolution of the extravasation. The suprapubic tube can then be capped and voiding trials begun until the patient can void with low residual urine volumes.

COMPLICATIONS

Intraoperative complications

Excessive bleeding rarely occurs, and it is usually controlled well with judicious use of electrocautery and, ultimately, vaginal packing.

Difficulty in closing the urethral mucosa may be encountered as the result of a large defect created during the excision of the diverticulum. In this situation, it may

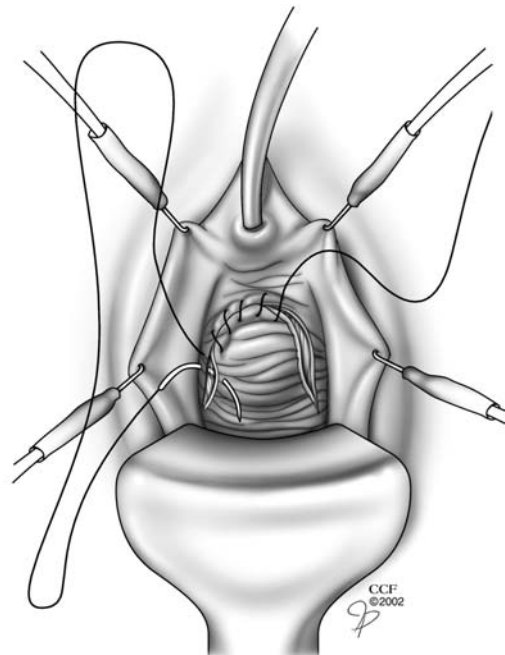


Figure 68.7 The anterior vaginal wall flap is advanced over the periurethral fascia suture lines to again avoid overlapping suture lines. A vaginal pack is placed and the urethral and suprapubic catheters are placed on gravity drainage. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

be necessary to expose the urethral wall further and to close the urethral mucosa over a smaller catheter.

In patients with severely inflamed or poor quality tissue, a fibrofatty labial (Martius) flap can be used between the periurethral fascia and the vaginal wall. This flap will add an extra protective layer, thereby helping to prevent the formation of a urethrovaginal fistula.

The finding of a large periurethral abscess may require a staged procedure in which the abscess is drained and excision of the diverticulum is performed as a secondary procedure.

A large proximal urethral diverticulum may extend into the trigone and bladder. Instillation of indigo carmine into the bladder will ensure bladder integrity, and cystoscopy after intravenous injection of indigo carmine may be performed in select cases to rule out ureteric injury. Further surgical challenges may be posed from a circumferential urethral diverticulum or one with a significant anterior component. In these cases, one may attempt to remove as much as possible from the lateral dissection or even transect the urethra and attain anterior access. One must, however, be well prepared to perform an extensive urethral reconstruction. Complex diverticula can be well imaged preoperatively with MRI so that the likelihood of an unsuspected and more complicated repair should be minimized.

Postoperative complications

Urethrovaginal fistula formation is the most difficult complication of diverticula surgery and should be treated after a reasonable period of healing. This may require at least 3 months of maturation to allow the inflammatory response after surgery to subside in order to optimize the subsequent surgical repair. Often, a Martius flap is placed over the repair to improve the chances of success. If an abscess forms, surgical drainage is required despite the potential damage to the repair.

Risk factors for diverticula recurrence include active urethral infection, difficult dissection, and excessive suture-line tension. Secondary urinary stress incontinence not present before surgery is rare but may develop in patients with prior anatomic defects because of dissection of the urethral support mechanisms. Severe incontinence caused by a non-functional sphincter may result from extensive dissection of the urethral wall. Surgical therapy for this condition may require a sling procedure or periurethral injection after a prudent period of healing typically 3–4 months postoperative.

CONCLUSIONS

The evaluation of the female urethral diverticulum has evolved greatly over the past several years. The main issue is that of suspected and accurate diagnosis further confirmed with MRI to determine the extent of the diverticulum. The operative approach involves prospective dissection of the tissue layers to facilitate reconstruction and prevent complications.

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69 Female urethral reconstruction

Courtenay K Moore

INTRODUCTION

Disorders of the female urethra requiring surgical intervention are rare and most commonly iatrogenic. The most common causes of surgical injury to the urethra include urethral diverticulectomy, anti-incontinence procedures, anterior colporrhaphy, and vaginal hysterectomy.¹ Injury to the urethra causing a urethrovaginal fistula may also occur. In industrialized nations, urethrovaginal fistulas are most commonly caused during vaginal and pelvic surgery, while in developing nations they are most commonly the result of obstetric trauma. Other causes of urethral injury include long-term indwelling urethral catheters, pelvic trauma causing laceration of the urethra or bladder neck, radiation, and carcinoma.

DIAGNOSIS

In the majority of patients the diagnosis of urethral injury is made at the time of vaginal examination. It is imperative to differentiate urinary leakage due to sphincteric incontinence from a urethral injury. This can be done using the double balloon urethrogram or occluding the urethral meatus with a finger and applying downward pressure to the posterior vaginal wall while the patient (with a full bladder) coughs orValsalvas.^{1,2} Cystoscopy is an invaluable tool in assessing the extent of the defect, detecting unrecognized secondary fistulas and assessing the quality of existing urethral tissue.

TIMING OF SURGICAL INTERVENTION

In the past surgical repair of urethral injuries was delayed for 3–6 months, allowing for the resolution of tissue inflammation and edema. However, more recent studies recommend early intervention, 3–6 weeks after the injury, provided there is no active inflammation or infection.

SURGICAL TECHNIQUE

While small urethral defects may be closed primarily, larger defects are technically more challenging and require considerable expertise and understanding of the anatomy.

The main principles of urethral reconstruction include:²

- (1) Not operating in the face of active inflammation or infection;
- (2) Adequate exposure and delineation of the defect;
- (3) Identification and avoidance of the ureters;
- (4) Debridement of devitalized tissue to ensure adequate blood supply;
- (5) Creation of tension-free multilayer watertight closure;
- (6) Avoid overlapping suture lines;
- (7) Adequate bladder drainage.

There are three approaches to urethral reconstruction: primary closure, vaginal wall flaps, and bladder flaps (anterior or posterior). While both vaginal wall flaps and bladder wall flaps successfully create neourethras, continence is only achieved in 50% of women undergoing anterior or posterior bladder wall flaps.

For all three types of procedure the patient is placed in the dorsal lithotomy position. Cystoscopy is performed to evaluate the extent of urethral injury and to identify the location and distance of the ureteral orifices relative to the urethral injury. If the ureteral orifices are in close proximity to the urethral defect, ureteral stents should be placed. A suprapubic tube and urethral catheter are placed for maximal drainage. Prior to making the vaginal incision it is imperative to determine the extent of injury and whether an advancement flap will be needed.

PRIMARY CLOSURE

Small injuries to the urethra may be closed successfully using 4-0 monofilament absorbable sutures. The closure must be tension free. If the urethral injury is the result of a urethrovaginal fistula, the edges of the fistula tract should be circumscribed widely to allow for a tension-free closure (Figure 69.1). After mobilization of the flaps, the urethral mucosa of the fistula is closed using a 4-0 monofilament absorbable suture. If possible a second layer of periurethral tissue should be closed over the urethral repair. The urethral defect is typically closed vertically, while the periurethral

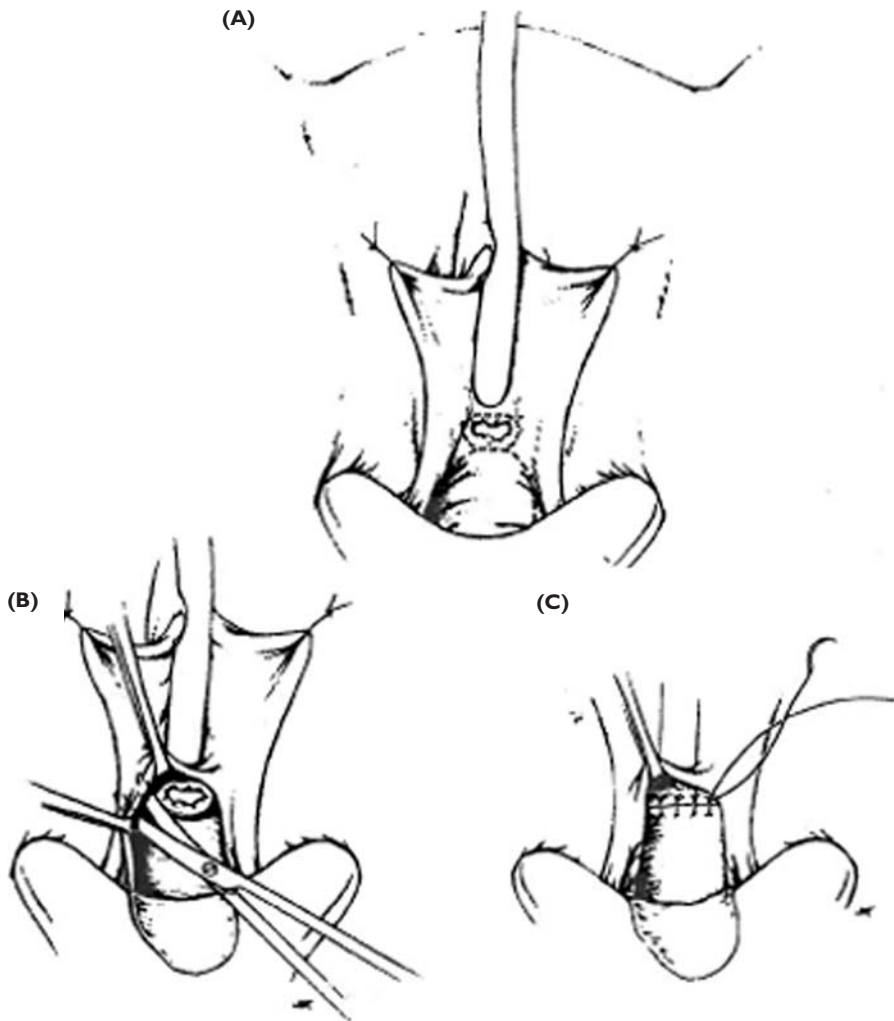


Figure 69.1 Primary closure of urethral defect. (A) The urethral fistula is circumscribed and an inverted 'U' shaped incision is made. (B) The 'U' shaped incision is reflected posteriorly and flaps are developed laterally. (C) The urethral defect is closed using absorbable sutures. The 'U' shaped incision is then closed.

layer is closed horizontally, thereby preventing overlapping suture lines.

VAGINAL WALL FLAPS

Tube graft

The tube graft is used in cases of extensive urethral injury that have sufficient vaginal wall epithelium for lateral mobilization. Prior to making any incisions, careful measurements must be taken. The vaginal wall must have enough epithelium to wrap tension free around a 16 Fr catheter.

After placement of a urethral Foley catheter, an inverted 'U' shaped incision is made to allow for mobilization of the anterior vaginal wall (Figure 69.2). The previously measured rectangular incision is made around the urethral meatus. The rectangular graft is then rolled over the Foley catheter to create a neourethra. If a Martius fat pad graft is needed it is prepared prior to

closure of the vaginal wall incision. A Penrose drain is placed and the inverted 'U' shaped vaginal wall incision is closed using a running 2-0 absorbable suture.

Advancement flap

An advancement flap is used when there is insufficient vaginal epithelium to mobilize flaps laterally (Figure 69.3). A 'U' shaped incision is made in the anterior vaginal wall. The flap is then rotated caudally to form the posterior and lateral walls of the neourethra. The flap is sutured in place over the urethral catheter. The anterior vaginal wall defect is then closed using a 2-0 absorbable suture.

LABIA MINORA PEDICLE GRAFT

The labia minora pedicle graft is used in cases where there is insufficient vaginal wall tissue for reconstruction.

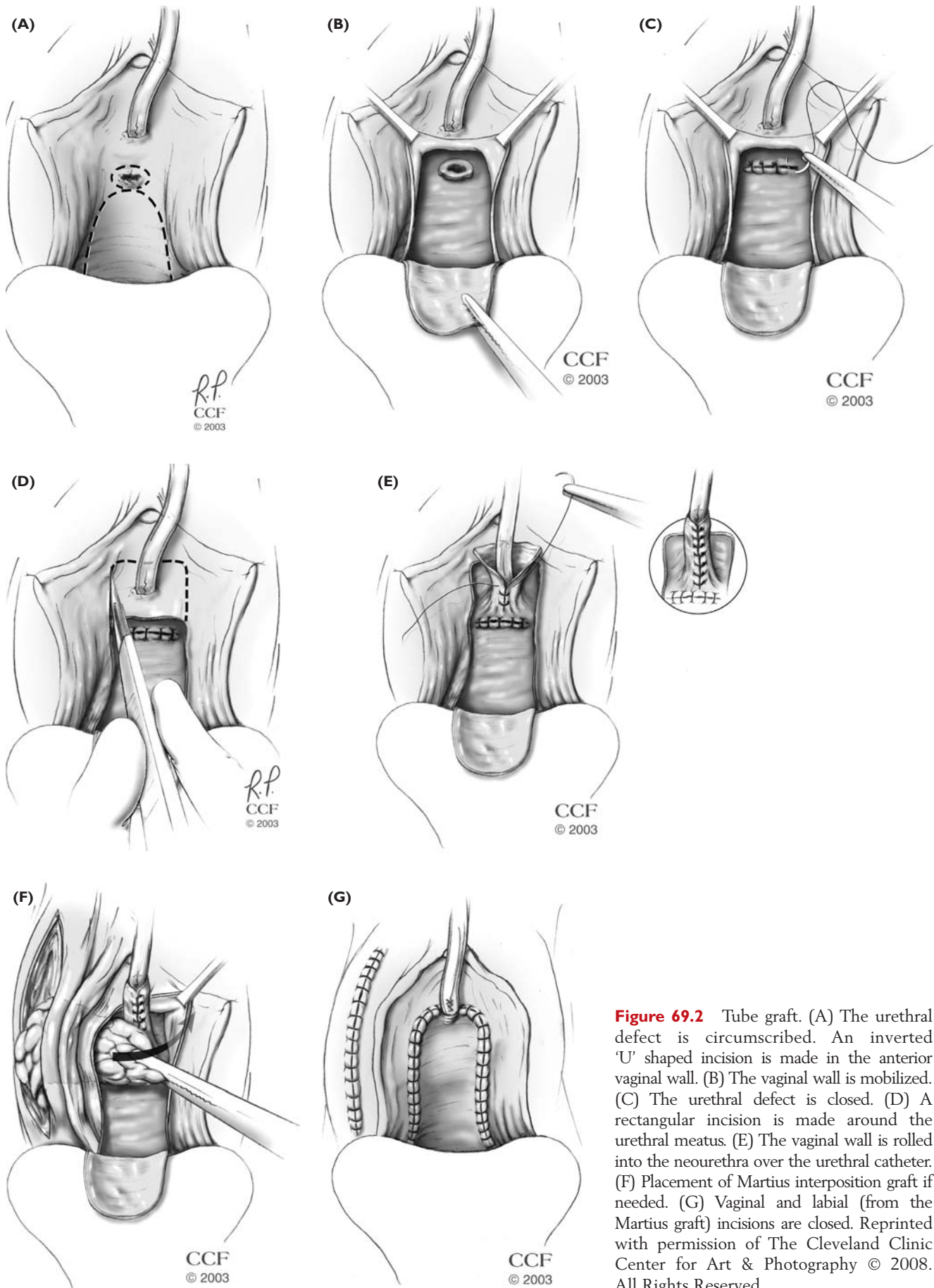


Figure 69.2 Tube graft. (A) The urethral defect is circumscribed. An inverted 'U' shaped incision is made in the anterior vaginal wall. (B) The vaginal wall is mobilized. (C) The urethral defect is closed. (D) A rectangular incision is made around the urethral meatus. (E) The vaginal wall is rolled into the neourethra over the urethral catheter. (F) Placement of Martius interposition graft if needed. (G) Vaginal and labial (from the Martius graft) incisions are closed. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

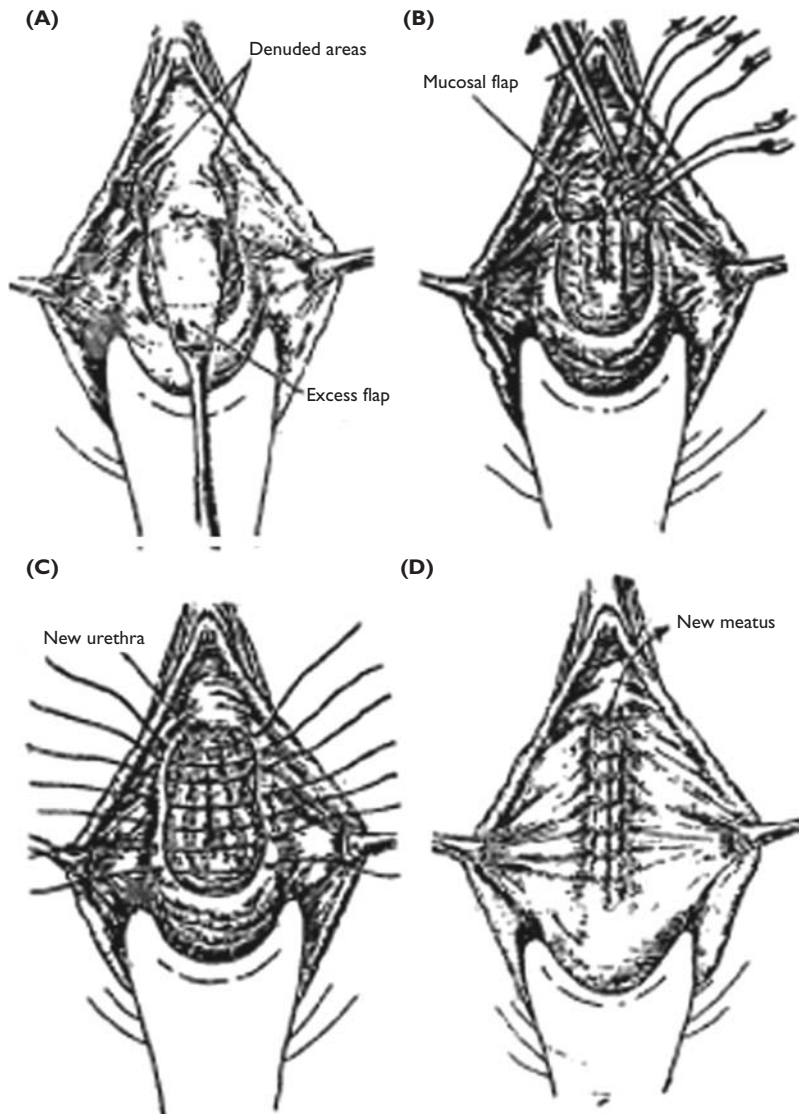


Figure 69.3 Advancement flap. (A) An inverted 'U' shaped incision is made in the anterior vaginal wall. (B) The 'U' shaped flap is then rotated distally and sutured in place as the posterior urethra. (C) The vaginal wall is closed. (D) Completed repair.

An oval incision is made in the labia minora as close to the urethra as possible (Figure 69.4). The incision must be long enough to roll over a 16 Fr Foley catheter without tension. The labial flap is then reflected medially and sutured over the urethral catheter. The labial incision is deepened and a pedicle graft based on either anterior or posterior blood supply is raised. The graft is passed beneath the vaginal wall and rotated such that the mucosal surface forms the inner wall of the neourethra. The labial and urethral incisions are closed using absorbable sutures.

BLADDER FLAPS

Bladder flaps are used primarily when vaginal wall flaps are not possible due to lack of adequate healthy vaginal wall tissue. The most commonly performed

bladder flap procedure is the Tanagho bladder flap urethroplasty. Initially described by Tanagho in 1970, this technique uses the anterior bladder wall to create a tubular neourethra. Unlike other bladder flaps which create a neourethra from the trigone, the Tanagho technique uses anterior bladder wall, thereby avoiding the need for ureteral reimplantation.³ This procedure has been used to treat women with complex urinary incontinence with significant loss of urethral tissue, urethral trauma, urethral excision for carcinoma, episadias, and large vesicovaginal fistulas.³⁻⁵

The procedure can be performed entirely via a vaginal approach (Figure 69.5). Once the anterior bladder wall is dissected free from the surrounding tissue to the level of the peritoneal reflection the anterior bladder flap is developed. A 3 cm × 3 cm area on the anterior bladder wall is measured. This area is then raised and rolled over a 16 Fr Foley catheter to create

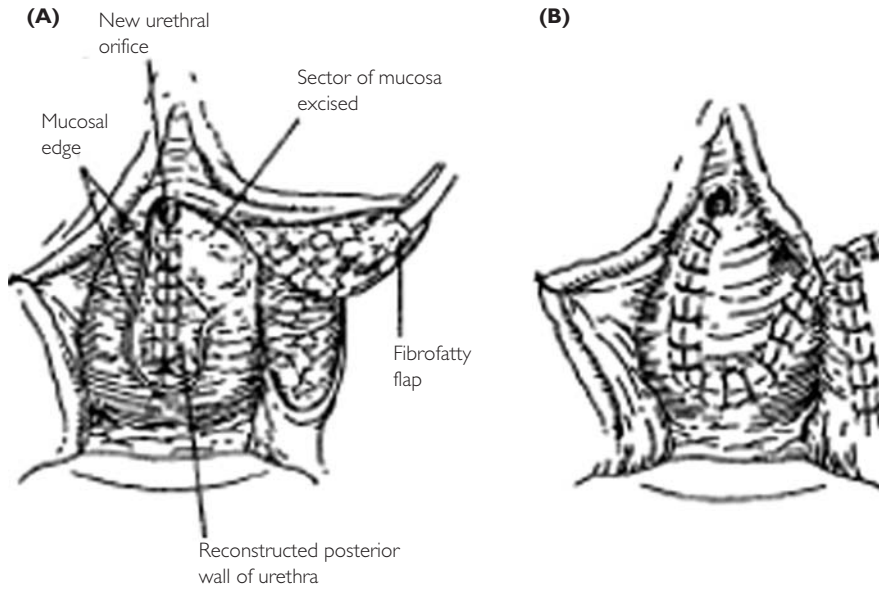


Figure 69.4 Labia minora flap. (A) An oval shaped incision is made in the labia minora, reflected medially and sutured over the urethral catheter. (B) Labial and urethral incisions are closed.

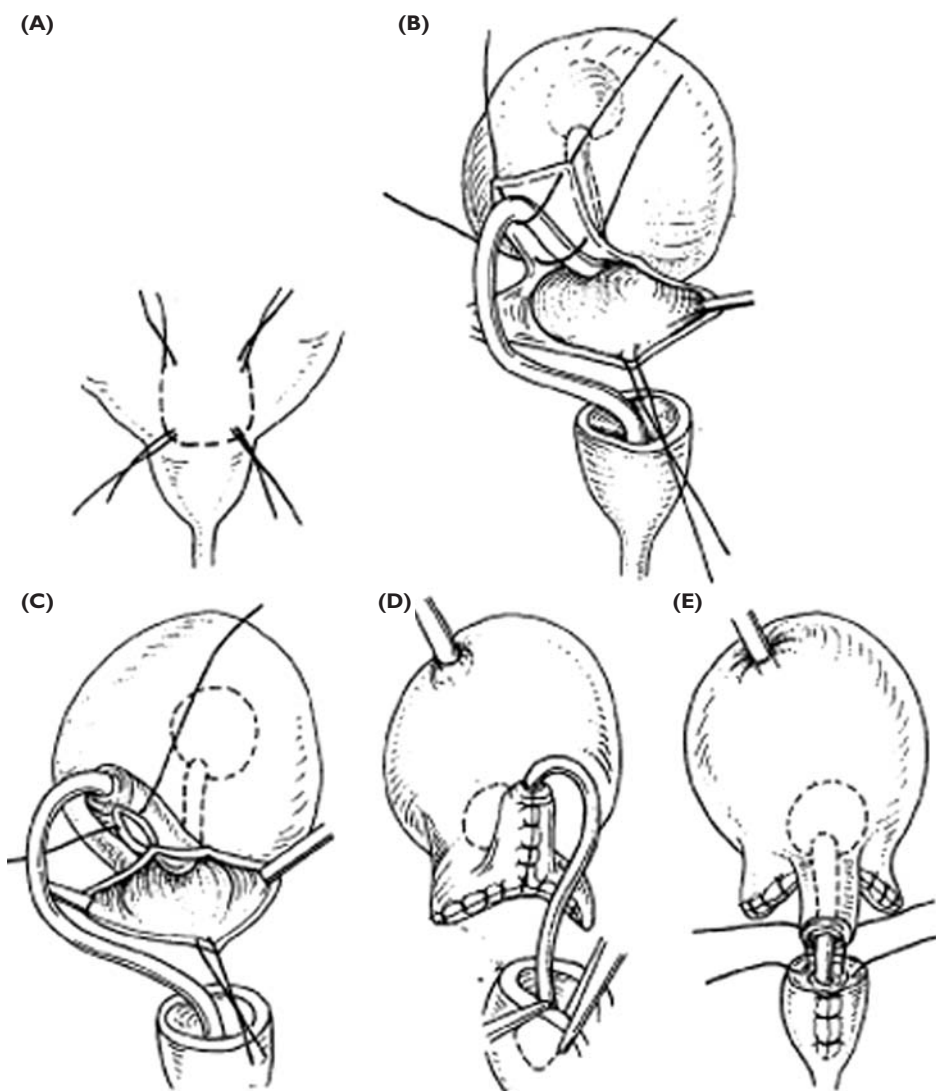


Figure 69.5 Tanagho anterior wall bladder flap. (A) After mobilization of the bladder a 3 cm × 3 cm anterior wall bladder flap is measured. (B) The urethra is transected at the site of the defect/injury. (C) The bladder flap is tubularized. (D) The posterior bladder is closed. (E) The neourethra is anastomosed to the distal urethral.

a neourethra. The bladder outlet is reconstructed by suturing the apex of the trigone to the base of the bladder flap, the remaining bladder outlet is closed in an inverted 'V' fashion. The neourethra is anastomosed to the remaining distal urethra.³⁻⁵ Postoperative complications include urethral stenosis, reduced bladder capacity, overactive bladder, and vesicovaginal fistulas.

CONCLUSION

While female urethral injuries are rare, it is important that reconstructive surgeons correctly identify them and perform the best procedure with the highest success rate. While the vast majority of urethral injuries can be repaired vaginally, women with extensive vaginal scarring and extensive loss of vaginal tissue may benefit from a bladder flap repair. As with most surgeries the first repair carries the highest rate of success, therefore it is imperative to follow these general principles when performing female urethral reconstruction:

(1) wait until any inflammation or infection has resolved prior to performing the procedure, (2) adequately expose the defect, (3) ensure a tension-free multilayered closure, (4) place a graft if warranted, and (5) maximize bladder drainage.

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70 Retropubic procedures for stress incontinence

Sarah E McAchran and Howard B Goldman

INTRODUCTION

The middle of the 20th century saw the advent of retropubic procedures for the treatment of stress urinary incontinence. In 1949, Marshall, Marchetti, and Krantz (MMK) reported the first series of their eponymous operation designed to elevate and mobilize the bladder neck and urethra by suturing these structures to the periosteum of the symphysis pubis with a bilateral series of three chromic sutures.¹ While effective, this operation was complicated by an osteitis pubis rate of 5–7%.² In 1961, Burch described an alternative retropubic approach.³ He found that he could cure both incontinence and cystourethroceles by suturing the paravaginal tissue to the ileopectineal (Cooper's) ligament. He asserted that the urethra could be supported by elevating the vaginal fascia lateral to the urethra. The Burch and MMK procedures became the standard of care during the latter part of the 20th century, based largely on the meta-analysis by Jarvis which reviewed over 20 000 patients who had undergone the procedures and found the long-term cure rate to be roughly 89% (Table 70.1).² In the minimally invasive era, most of the recent literature on these procedures is dedicated to exploring the feasibility and indications for performing them both laparoscopically and robotically. The recent popularity of various types of slings has challenged the gold-standard status of these classic retropubic procedures.

PHYSIOLOGIC CHANGES

The exact mechanism by which these procedures cure incontinence is unknown. Burch originally proposed

that it may be secondary to the elevation and stabilization of the bladder neck and urethra. It is known that the MMK and Burch operations rarely change the relationship between intraurethral and intravesical pressures. They make the proximal urethra and bladder neck an intra-abdominal organ and equalize intra-abdominal pressures on the bladder wall that are precipitated by a Valsalva maneuver. Digesu et al looked at magnetic resonance imaging (MRI) findings in 28 women before and 1 year after open Burch colposuspension.⁴ In all, 86% were cured. In this population the distance between the levator ani muscle and the bladder neck was significantly shorter than in those who had failed to achieve continence.

OPERATIVE PROCEDURE

A preoperative prophylactic antibiotic, such as a first-generation cephalosporin, is recommended. After the application of pneumatic compression boots, the patient is placed in the supine lithotomy position. Both the abdomen and vagina should be prepped and draped so that they are accessible in the sterile field. A Foley catheter is inserted. When performed open, either a lower midline or transverse (Pfannenstiel) incision is acceptable. After incising the rectus fascia, the space of Retzius is entered. Bladder and urethrovesical junction identification are aided by the Foley balloon (Figures 70.1 and 70.2). If a concomitant intraperitoneal procedure is required, it should be performed first.

After entering the retropubic space, a sponge stick can be used to depress the urethra and anterior vaginal wall. The bladder is then carefully dissected from the posterior

Table 70.1 Objective cure rates for first procedures and for recurrent incontinence. Data are presented as means.

Procedure	First procedure (%)	Recurrent incontinence (%)
Bladder buttress	67.8	ND
MMK	89.5	ND
Burch colposuspension	89.8	82.5
Bladder neck suspension	86.7	86.4
Sling	93.9	86.1
Injectables	45.5	57.8

Adapted from reference 2.

MMK, Marshall, Marchetti, and Krantz; ND, not detected.

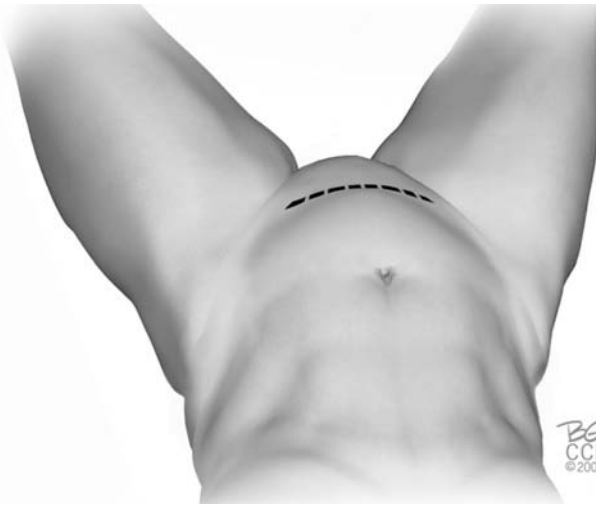


Figure 70.1 A Pfannenstiel incision is made superior to the pubic symphysis. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

aspect of the symphysis by blunt or sharp dissection until the paravaginal tissue lateral to the urethra, bladder neck, and bladder base is identified as a conspicuous white area. To aid in dissection, the surgeon's non-dominant hand is placed in the vagina with the index and middle fingers on one side of the proximal urethra (Figure 70.3). Forceful elevation of the surgeon's vaginal fingers will help to expose the periurethral fascia and vaginal wall. Midline dissection should be avoided, thereby preserving the musculature of the urethra and urethrovesical junction. The obturator foramen and its neurovascular bundle define the lateral margin of the dissection field. Injury to these structures should be avoided.

Once the paravaginal tissue is exposed bilaterally, a finger is again inserted in the vagina to aid in identification of the proper area for suture placement. Either a permanent monofilament or delayed-absorbable monofilament suture can be used. These sutures can be double armed. A small curved needle, such as an SH, is used. Before passing each suture, the position is confirmed by palpating the bladder and inserting a finger in the vaginal fornix. The vaginal finger should be elevating the most mobile and pliable portion of the vagina lateral to the bladder neck. The bites in the para-urethral fascia should not be positioned too closely to the bladder neck and urethra as this may lead to postoperative voiding dysfunction. The proximal suture is placed slightly proximal to the bladder neck (Figure 70.4). The distal suture is placed 2 cm lateral to the proximal third of the urethra. The blood vessels comprising the plexus of Santorini should be avoided, however, if bleeding develops it can generally be stopped by elevating the finger in the vagina. This allows for identification and either fulguration or ligation of specific vessels.

MMK PROCEDURE

In the MMK operation, the suture that has been placed in the periurethral tissue is tied to the periosteum of the pubic symphysis (Figure 70.5A). To determine the point of fixation of the urethra to the pubic symphysis, elevate the two vaginal fingers such that the vesical neck contacts the bone. Note this position, as it is where the sutures will be placed into the pubic periosteum. The needle is placed medially to laterally against the periosteum and turned with a simple wrist action. Depending

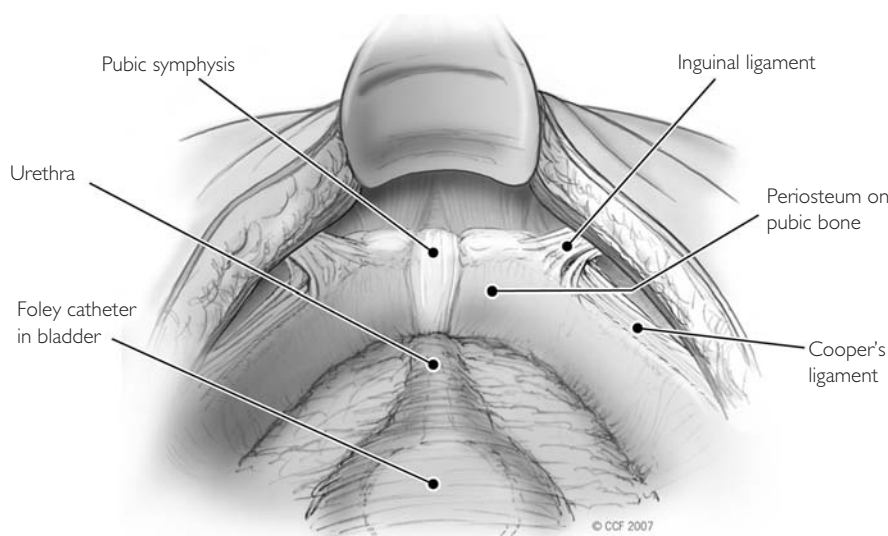


Figure 70.2 The space of Retzius is entered, allowing for identification of pubic symphysis and Cooper's ligament. The Foley balloon should be palpable in the bladder. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

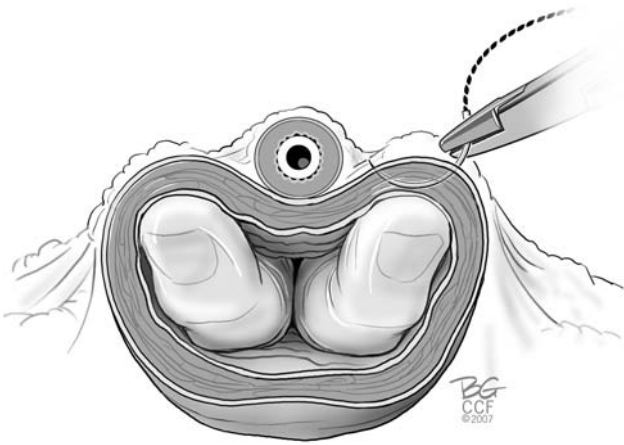


Figure 70.3 To aid in dissection, the surgeon's non-dominant hand is placed in the vagina with the index and middle fingers on one side of the proximal urethra. Forceful elevation of the surgeon's vaginal fingers will help to expose the periurethral fascia and vaginal wall. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

on the width, thickness, and availability of periosteum, this suture may incorporate the cartilage in the midline. An additional one or two sutures are placed. Two fingers in the vagina are used to tent up the anterior vaginal wall while the sutures are being tied (Figures 70.5B and C).

BURCH COLPOSUSPENSION

In the Burch operation, the sutures that have been placed through the periurethral tissue are brought out through the ileopectineal ligament, also known as the conjoint tendon, or Cooper's ligament (Figure 70.6A). Again, the most caudad suture should be opposite the bladder neck, about 1.5–2 cm lateral to the urethra. The sutures are not tied until they have all been placed through the ligaments bilaterally (Figure 70.6B). As with the MMK, two fingers in the vagina are used to tent up the anterior vaginal wall while the sutures are being tied. The most caudad sutures are tied first. The remaining sutures are tied on alternating sides to ensure balanced support. The goal is not direct tissue apposition. A bow-strung, non-approximating loop suture is created by placing a finger between the conjoint tendon and the periurethral tissue such that, when tied, there is a 2 cm or fingerbreadth's space between the two (Figure 70.6C). This maneuver helps prevent urethral occlusion and subsequent urinary retention or voiding dysfunction.

When initially described, a suprapubic tube was placed as well, however, several studies have failed to show a difference in cure rate between postoperative

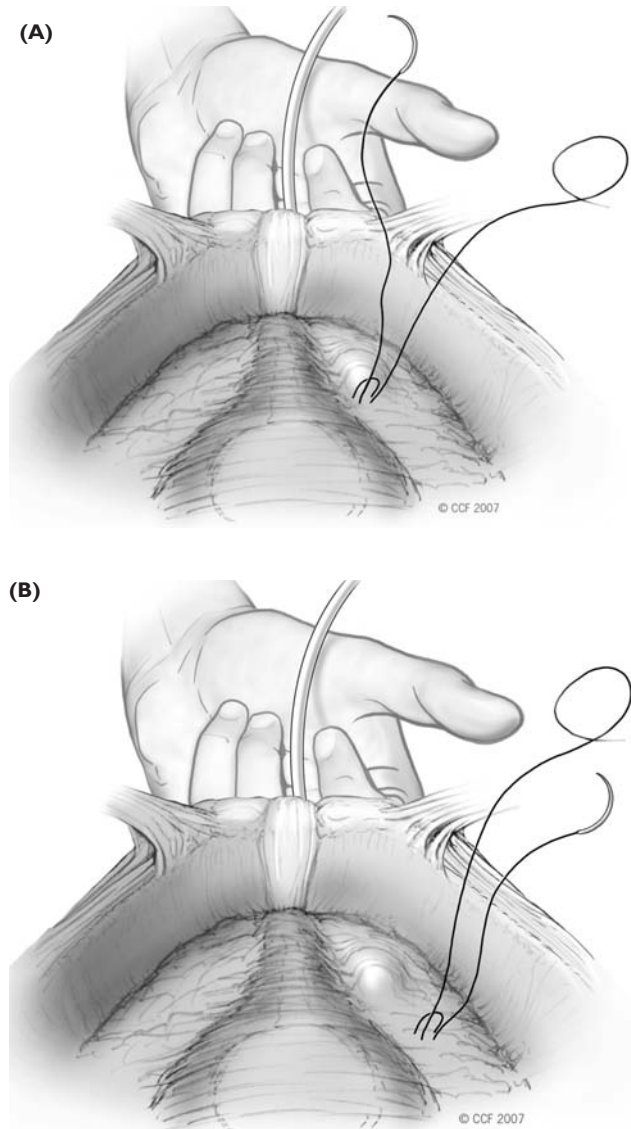


Figure 70.4 With the bladder dissected from the posterior aspect of the symphysis and the surgeon's non-dominant hand in the vagina, the paravaginal tissue is exposed and the sutures are placed through the paraurethral fascia slightly proximal to the bladder neck. Note that the initial suture placement is the same for both the MMK (A) and Burch procedures. (B) Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

suprapubic and urethral drainage.^{5,6} Originally, continuous bladder drainage was recommended for 2–6 days. In a recent, prospectively randomized study, 86 patients who underwent a Burch procedure had their catheters removed on either postoperative day 1 or 5.⁷ There were no statistical differences found between the two groups with respect to the rates of urinary tract infections, postoperative retention, voiding dysfunction, other complications, or cure. This suggests that a shorter period of catheterization is reasonable.

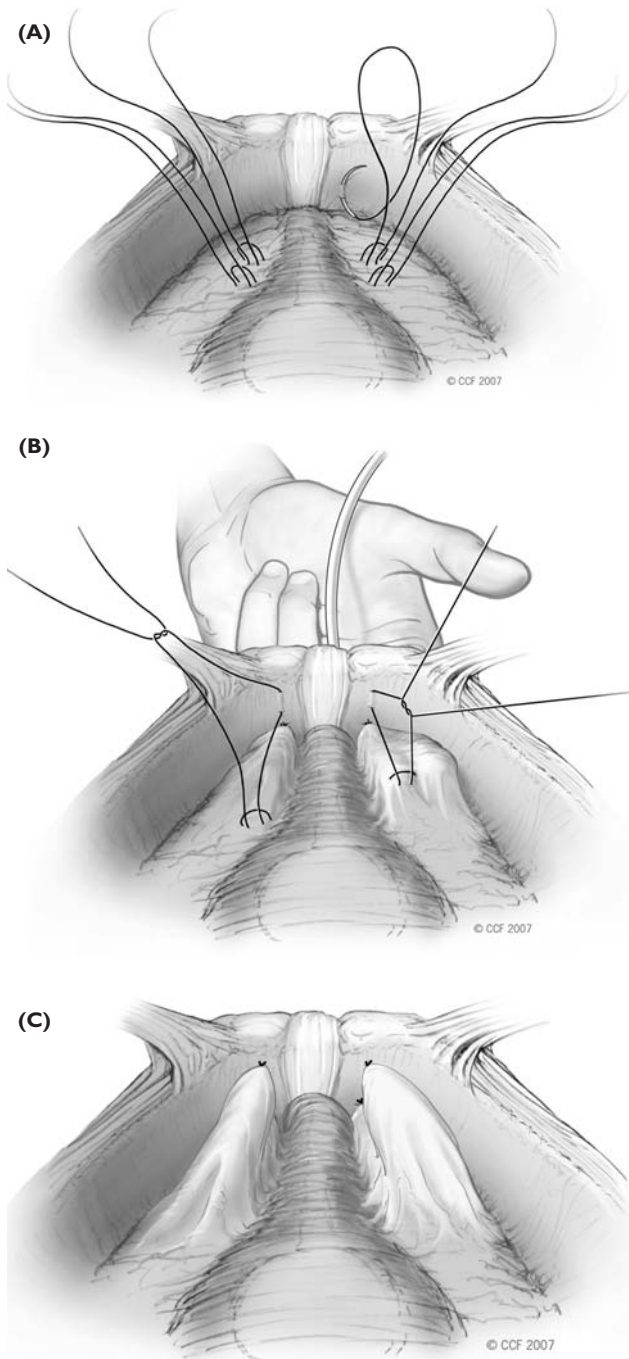


Figure 70.5 In the MMK (A) the suture is tied to the periosteum of the pubic symphysis. (B) Two fingers should be used to tent up the vagina while the sutures are being tied. (C) Note that, in the MMK, the paraurethral tissue is directly approximated to the pubic symphysis. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

LAPAROSCOPIC AND ROBOTIC RETROPUBIC PROCEDURES

The laparoscopic approach to the Burch procedure was first described by Vancaillie and Schuessler in

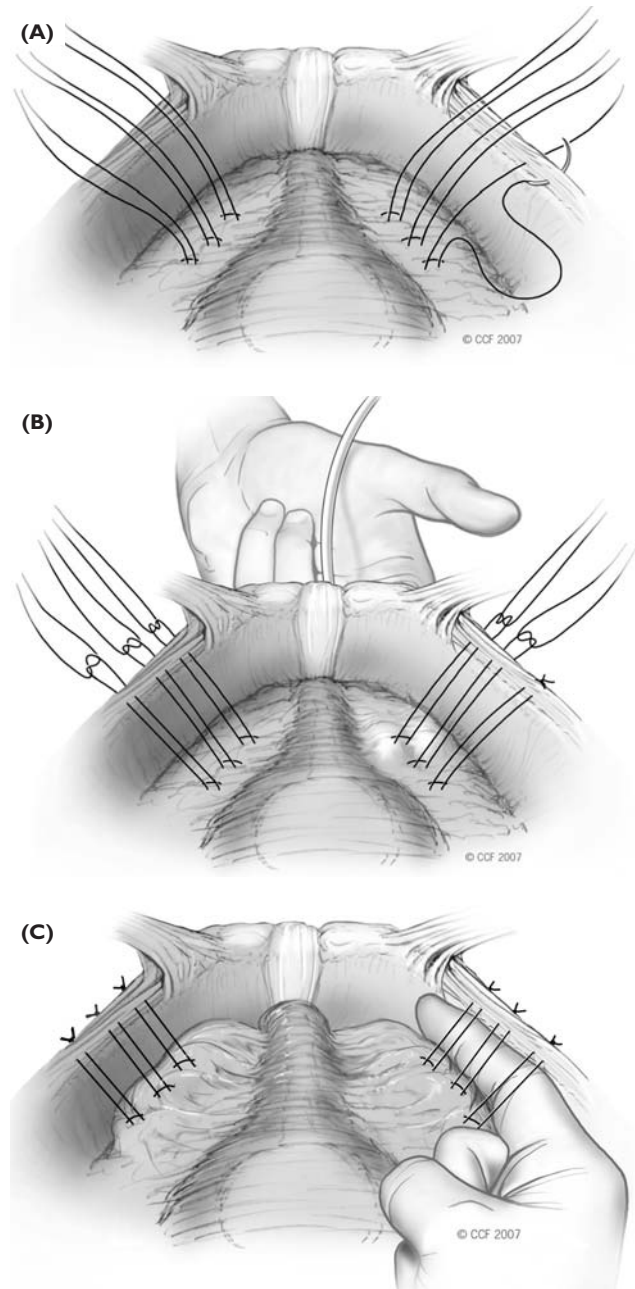


Figure 70.6 In the Burch, (A) the sutures that have been placed through the paraurethral tissue are brought out through the ileopectineal ligament. The sutures are not tied until they have all been placed through the ligaments bilaterally. (B) As with the MMK, two fingers are used to tent up the vagina while the sutures are being tied. (C) Remember that the goal is not direct tissue apposition. The non-approximating loop suture should be able to accommodate one finger space between the vagina and the ileopectineal ligament. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

1991.⁸ It may be performed via an extraperitoneal or transperitoneal approach. The patient is positioned, prepped, and draped as if for an open procedure. Laparoscopic ports are placed in a diamond configuration. If an extraperitoneal approach is chosen then a

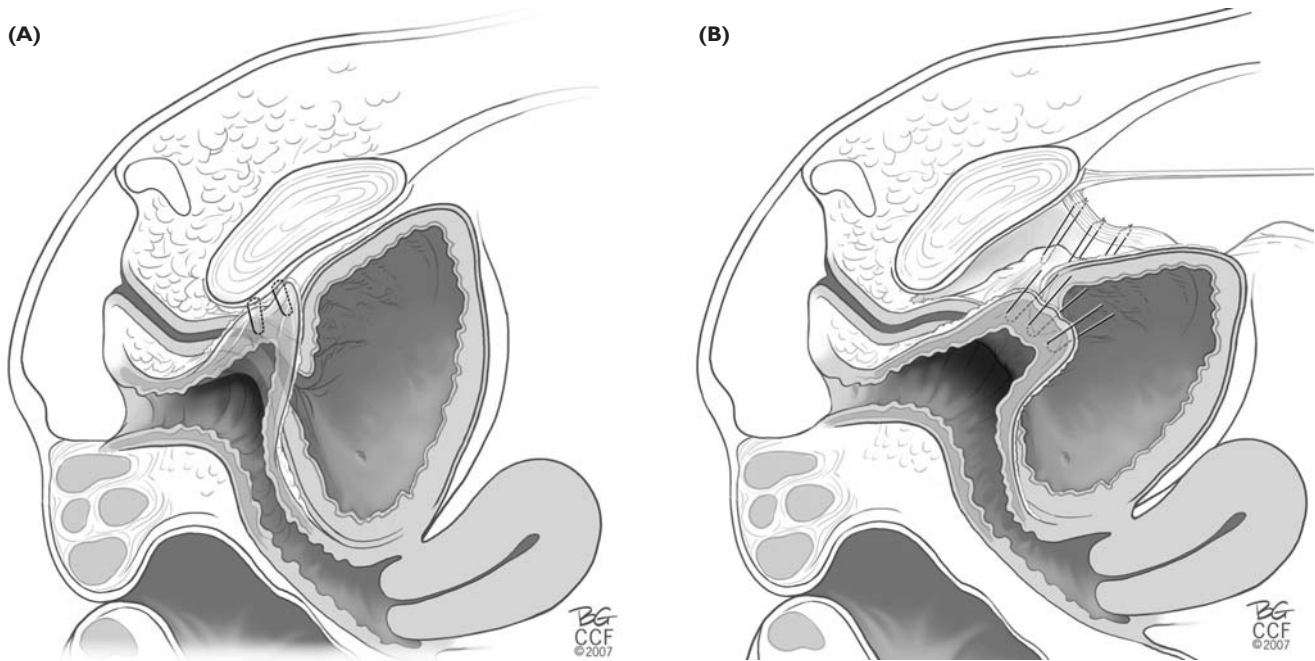


Figure 70.7 In this sagittal view, the different anatomic outcomes between the MMK (A) and the Burch (B) are clearly illustrated. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

balloon dilator is placed initially. Much of the dissection is already accomplished after extraperitoneal balloon inflation. The procedure is then performed in exactly the same manner as for open surgery. In the transperitoneal approach, ports are placed in the same configuration. After creation of the pneumoperitoneum, a vertical incision is made just medial to the left obliterated umbilical ligament aiming towards the pubic bone. This provides entry into the retropubic space. Because a fair amount of intracorporeal suturing must be performed, the laparoscopic Burch procedure demands a skilled laparoscopist.

In comparative studies between the laparoscopic Burch, transvaginal bladder neck suspension, and open Burch colposuspension, the estimated blood loss is similar. As expected, operative times are consistently longer with the laparoscopic approach. Also as expected, after laparoscopy, the recovery is more brisk, the postoperative analgesia requirement is decreased, and the hospital stay is shorter. Initial studies of the outcomes of the laparoscopic Burch procedure suggested that the repair was not as durable as the open approach with continence rates of only 35–40% at 3 years. However, a recent, randomized trial of 200 women with stress urinary incontinence, comparing laparoscopic with open Burch found no difference in urodynamic outcome, symptoms, and validated quality of life questionnaires at 3–5 years of follow-up.⁹ The

authors postulate that earlier trials comparing surgical outcomes were complicated by different surgical techniques for the open and laparoscopic approaches, such as a different number or type of sutures. In this study, a traditional Burch procedure was performed and the only difference between the two arms of the trial was the type of initial incision.

COMPLICATIONS

Bleeding from the paravesical venous plexus is the most common complication of retropubic urethropexy. As previously mentioned this can be controlled with undersewing or diathermy, but often stops when the sutures are tied. The bladder or urethra may also be injured, but when promptly recognized and repaired causes minimal long-term sequelae.

Postoperative complications include hemorrhage and hematoma formation, nerve injury, lower urinary tract injury, urinary tract infection, osteitis pubis, voiding dysfunction, and de novo detrusor instability. There is also a 7–17% incidence of enterocele and rectocele formation. If a hematoma is suspected it may be diagnosed by ultrasound or computed tomography. Serious postoperative bleeding can be stopped with embolization or, rarely, laparotomy. Nerve injuries are most often the result of positioning or retractor placement.

The peroneal, femoral, or sciatic nerves are the most often affected. Dissection and placement of sutures are more likely to injure the obturator nerve or entrap the ilioinguinal nerves. Fortunately, damage to the ureter is rare, but has been described following both the Burch and MMK. The rate of postoperative cystitis is about 8%. Osteitis pubis is a rare inflammatory, non-infectious, process of the pubic symphysis and is reported following 5% of MMK procedures. It is best treated with a combination of rest, analgesics, and steroids.

Voiding dysfunction following retropubic procedures is a well documented complication, with a highly variable incidence reported from 1.7 to 25%. Typically, the resumption of a normal voiding pattern takes 10–14 days. However, the Burch colposuspension produces significant changes in postoperative voiding function which may persist even 3 months after surgery. Urodynamics performed 3 months after colposuspension demonstrated reduced flow rates and increased voiding pressures. Various preoperative urodynamic factors were suggested to predict which patients are prone to have voiding difficulties, such as detrusor pressures less than 15 cmH₂O, or voiding with a Valsalva maneuver. Other reports have not been able to confirm this. In general such patients should be counseled about this complication and about the possible need for intermittent self catheterization postoperatively.

Detrusor instability arises de novo in as many as 27% of women postoperatively, more often in women who have had previous anti-incontinence operations.¹⁰ Early onset detrusor instability may be due to inflammation of the surgical site, a urinary tract infection, a foreign body in the bladder, or bladder outlet obstruction. When an etiology can be identified, it should be treated. De novo detrusor instability is often sited as a cause of failure.

BURCH COLPOSUSPENSION IN THE ERA OF THE TENSION-FREE VAGINAL TAPE

The tension-free vaginal tape (TVT) procedure was introduced in 1996 as a treatment for stress urinary incontinence and has gained brisk and widespread acceptance. It provides the advantages of low morbidity, minimal anesthetic requirement, and no need for an overnight hospital stay. These factors combined with its reported 7-year objective and subjective success rate of 81% make it the most competitive gold-standard

challenger. Ward and Hilton published 2-year follow-up data on their prospective, randomized trial comparing TVT with open Burch colposuspension.¹¹ At 2 years, they found the TVT to be as effective as the Burch for the treatment of stress incontinence. A 5-year follow-up is planned.

CONCLUSIONS

Owing to its documented long-term success rates, the open Burch remains the gold-standard surgical treatment of stress urinary incontinence. When the open procedure is duplicated laparoscopically, this approach proves equally effective. Patients should be informed of the possibility of postoperative voiding dysfunction and de novo detrusor instability.

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71 Slings for female stress urinary incontinence

Edward J McGuire and Rebecca U Margulies

HISTORY

Slings in one form or another have been in use for more than 100 years. German surgeons reported on various slings shortly after 1900. Aldridge and Millen in England used slings as did gynecologic surgeons at Johns Hopkins, Ridley in Atlanta, and many others.¹⁻³

The introduction of synthetic materials for slings was gradual and sporadic at first. In part, this was related to the tendency of the materials used for slings to erode into the urethra or bladder. The materials used included Marlex (CR Bard Billerica), Gore-Tex (WL Gre Inc Network, DE), silicone (usually adapted from prostheses made for other purposes), and woven material impregnated with collagen. The most successful were Marlex slings which were simply placed behind the urethra and not sutured or fixed in any way. Success with the Marlex sling was about 75%.^{4,5} Slings of other materials were abandoned because erosion was a common problem.

The 'standard' sling for many years was made from autologous fascia. While such slings had been used for both primary and recurrent stress incontinence, they were regarded as difficult to do and associated with a high rate of bladder outlet obstruction and other complications. During the 1970s and 1980s surgeons gradually stopped doing classical anterior repairs and the 'Kelly' plication, and the standard procedure to correct stress incontinence became a retropubic suspension.^{6,7} While retropubic suspensions, when compared with the older vaginal procedures, had a much lower failure rate, they did occasionally fail immediately. In these cases, slings were used to correct poor function of the urethra, which based on videourodynamic evaluation seemed to be the reason that the retropubic procedure had failed.⁸

In the 1970s, videourodynamics were used to characterize primary and recurrent stress incontinence. As a result, stress urinary incontinence (SUI) was loosely divided into three major categories. Type I was when leakage was associated with limited urethral mobility. This was thought to be a suitable condition for an anterior repair. Type II SUI was associated with greater degrees of urethral mobility such that the internal meatus was pushed by abdominal pressure to a position

lower than the rather fixed external urethral meatus. This condition was thought suitable only for a retropubic suspension and not an anterior repair. In type III stress incontinence, minimal abdominal pressure was required to cause leakage and urethral mobility was not a factor in leakage. Patients who failed retropubic suspensions tended to be in the latter group (type III) where low abdominal pressures were associated with leakage.⁹ This was later termed 'intrinsic sphincter deficiency' (ISD), meaning that there was something wrong with the urethral closing mechanism as opposed to the transient loss of continence associated with abdominal pressure driven mobility of the urethra as in type I and II varieties of stress incontinence.

There is truth in these observations but currently no one agrees on the correct method to determine whether the urethra suffers from intrinsic deficiency or not. Both leak point pressure and urethral pressure profile data have been used to identify intrinsic sphincter deficiency. The two measurements do not correlate very well and they probably measure different things.¹⁰⁻¹²

The relatively recent introduction of loosely woven polypropylene slings has changed stress incontinence surgery so profoundly that the older viewpoints are now only of historical interest with some notable exceptions. These new slings are generally placed with little tension, behind the mid- or more distal urethra, rather than at the bladder neck. This placement is the result of recognition that support of the urethra is exerted by the pubourethral ligaments which were first clearly described by Zacharin in Australia.¹³ Petros and Ulmsten described a 'uniform theory' of the pathogenesis of stress incontinence.¹⁴ They implicated a lack of mid-urethral support, the problem described by Zacharin, as the usual problem in most patients with stress incontinence. Therefore, they placed their sling about the distal third of the urethra 'without tension' in relation to this theory.¹⁵ Delancey's theory,¹⁶ based on anatomic data of the hammock support of the urethra conveyed by the vagina is slightly at odds with the Petros-Ulmsten theory, but in the end synthetic slings were so successful for all kinds of stress incontinence that the arguments and theories no longer mattered.

A case in point is the problem of 'mixed incontinence'. For years surgeons were urged to determine

whether detrusor instability was present in patients with stress incontinence, by doing a cystometrogram. If the cystometrogram was positive that patient was thought to be a poor candidate for any operation for stress incontinence. This is no longer advocated, and because the outcome of synthetic slings is so good, no one would bother with a cystometrogram in any case. A similar thing happened to intrinsic sphincter deficiency. The condition, identified by urethral pressure profile data, does not seem to be a risk factor for failure of a tension-free vaginal tape (TVT) or transobturator tape (TOT).^{17,18}

There are some problems with synthetic slings including that they can erode, they can cause voiding dysfunction, they may need to be removed partly or completely, and there may be late problems as patients age. On the other hand, for most patients with primary stress incontinence, these are the procedures of choice at the moment. There are good 5-year data which support their use. These data do note a certain failure rate, and some authors suggest that results are not as good in women with low leak point pressures or those with mixed incontinence, however that variable is defined.^{19,20}

THE WORST KINDS OF STRESS INCONTINENCE

The worst variety of stress incontinence, in terms of severity and complexity of surgical correction is associated with non-function, or poor function, of the proximal sphincter. This falls outside the anatomic descriptions of Zacharin and the uniform theory of stress incontinence from Petros and Ulmsten. It is a condition which can occur with normal vaginal hammock support. It is associated with an open bladder neck in the upright position, at all stages of bladder filling and leakage at low to very low abdominal pressures (Figure 71.1). This is not the same condition seen in the majority of people with stress incontinence. It occurs in some 9% of patients who have never had an operation for stress incontinence, and becomes much more common in patients who have failed one or more operations for stress incontinence.²¹ This is true, pure, intrinsic sphincter dysfunction.

NEURAL CAUSES OF INTRINSIC SPHINCTER DYSFUNCTION

Total non-function of the proximal sphincter and serious stress incontinence is common in patients with myelodysplasia, sacral agenesis, and T12–L1 spinal



Figure 71.1 Non-functional proximal urethra. Upright cystogram during a urodynamic study under fluoroscopic control. There was loss of function of the proximal sphincter from the bladder neck to the distal sphincter. This condition is associated with severe stress incontinence even if the distal sphincter functions normally.

cord injuries. Urethral non-function here is directly related to loss of the sympathetic innervation of the urethra at a central level. This opens the proximal urethra. Closure of the non-functional proximal urethra is the only way to gain continence, and compression of the urethra is required to achieve this.²² One cannot safely use synthetic material in these cases. Autologous fascia is the best material for these conditions. Autologous fascia slings used in children with myelodysplasia appear to ‘grow’ with the child. For example, slings done in school children, or even infants, do not need to be redone with time, and most such slings survive vaginal deliveries. Non-function of the proximal sphincter and severe stress incontinence can result from extirpative pelvic surgery for uterine or rectal carcinoma as well. This is related to a neural injury associated with the surgery. In the latter cases, distal volitional sphincter function is normal but does not prevent stress incontinence.

ACQUIRED CAUSES OF INTRINSIC SPHINCTER DYSFUNCTION

Proximal urethral non-function is seen in women with severe unremitting stress incontinence after labor and delivery. The urethra may or may not be mobile but the abdominal leak point pressure is low and the bladder outlet partly open. The resultant stress incontinence is very severe and does not improve with time (Figure 71.2).

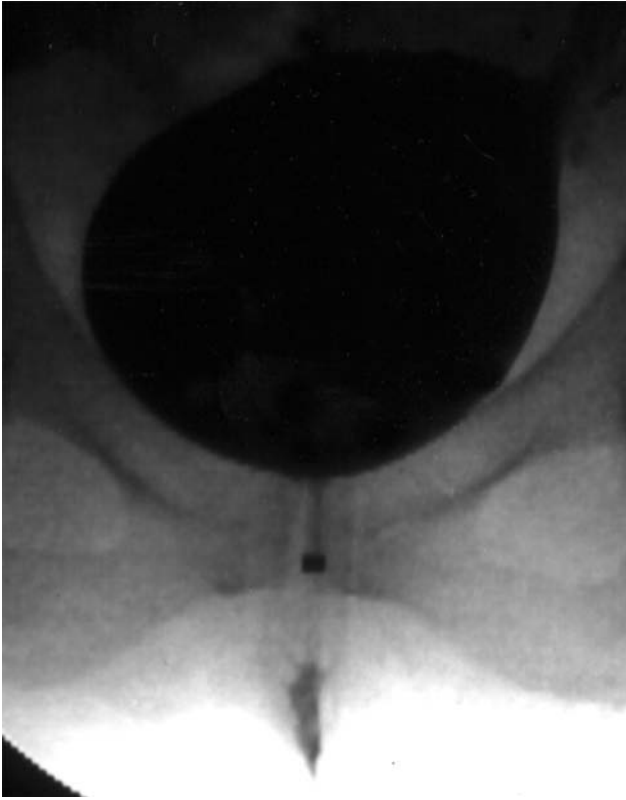


Figure 71.2 Image from a videourodynamic study from a 31-year-old woman with severe postpartum stress incontinence. The proximal sphincter did not function. The distal sphincter was normal. There was stress incontinence at an abnormal pressure of 42–44 cmH₂O. There was no urethral mobility. This stress incontinence was associated with loss of proximal sphincter function related to childbirth.

Failure of prior operative procedures to resolve stress incontinence, especially if the incontinence appears to the patient to be worse than her preoperative condition, is usually associated with very low leak point pressure stress incontinence and an open bladder neck (Figure 71.3). When patients have failed one or two TVT procedures or a TOT of one kind or another, the usual finding is a urethra which, with coughing, fills down to the place where the TVT or TOT closes the urethra and then leaks across the compressed area of the urethra (Figure 71.4). Generally there is no motion of the urethra. Another distal sling will not obviate this kind of leakage.

Erosion of a synthetic or natural tissue sling into the urethra requires removal of the sling and sometimes closure of the defect in the urethra. Especially with 'donor' fascia slings, and sometimes synthetic slings, recurrent stress incontinence can be severe (Figure 71.5). In these cases we use autologous fascia only. Especially with donor fascia slings but sometimes with

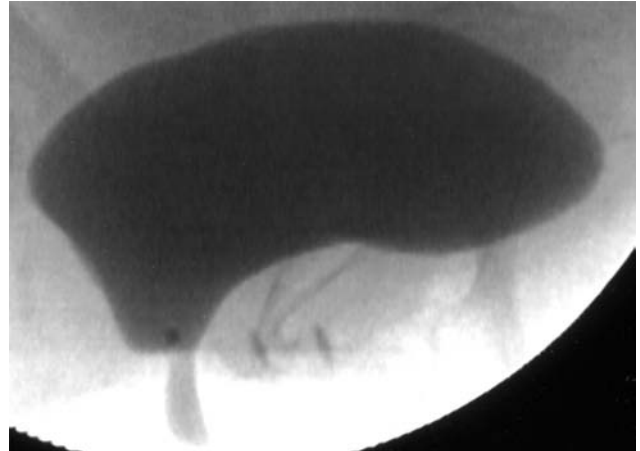


Figure 71.3 Videourodynamic study from a 55-year-old woman with severe persistent stress incontinence following a bone-anchored donor fascia sling. There was inadequate compression of the urethra by the sling and stress incontinence despite 'support' of the urethra.



Figure 71.4 Videourodynamic study from a 64-year-old woman with persistent stress incontinence after a transobturator tape procedure. The proximal urethra was not functional and the sling did not exert enough pressure on that segment of the urethra to close it.

synthetic slings, erosion and removal is followed by persistent urethrovaginal or vesicovaginal fistula formation. This complicates subsequent stress incontinence surgery as identification of a fistula in the proximal or distal urethra may be difficult when the

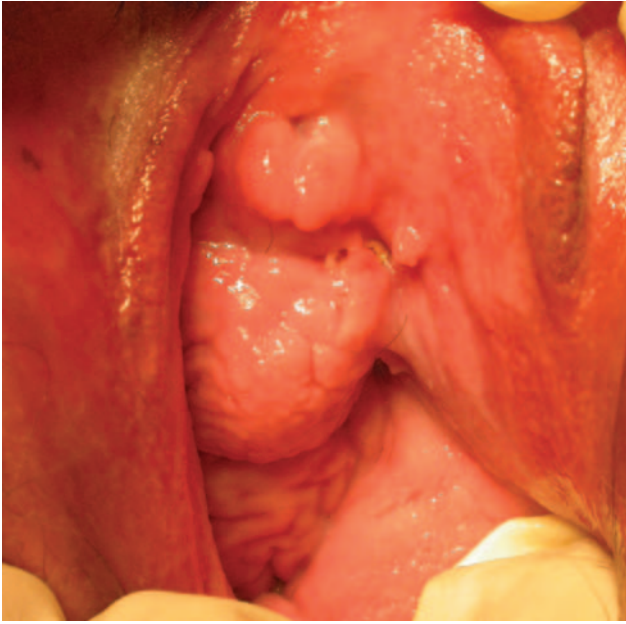


Figure 71.5 Vaginal examination in a 38-year-old woman with pain, vaginal bleeding, and dyspareunia after a tension-free vaginal tape (TVT) procedure. Erosion of the mesh on the left side can be seen. The course of the TVT is marked by the indentation of the vaginal wall.

proximal urethra is non-functional and there is gross stress leakage (Figure 71.6).

Pelvic trauma with pelvic fracture can be associated with severe stress incontinence. The first attempt to repair this is the most likely to be successful and the degree of compression required at the bladder neck is such that an autologous fascia sling is the best material to use. The problems here involve finding a place to secure the sling, and sling passage through the retro-pubic space. Lateral fixation such as that achieved with a TOT type procedure does not generate enough closing force on the proximal urethra and does not work in these cases. Passage of large needles within the pelvis is difficult and dangerous as all anatomic relationships are distorted or lost.

Patients with neurogenic vesical dysfunction who are using intermittent catheterization to empty the bladder are not good candidates for synthetic slings if they develop stress incontinence. The chronic bacteriuria and the daily trauma of catheterization are not compatible with a long sling life where synthetic materials are used. In these cases, standard autologous fascia bladder neck slings are the most appropriate procedures (Figure 71.7).

In summary, if one can establish that a poorly functional or non-functional proximal sphincter is the problem associated with stress incontinence, then an

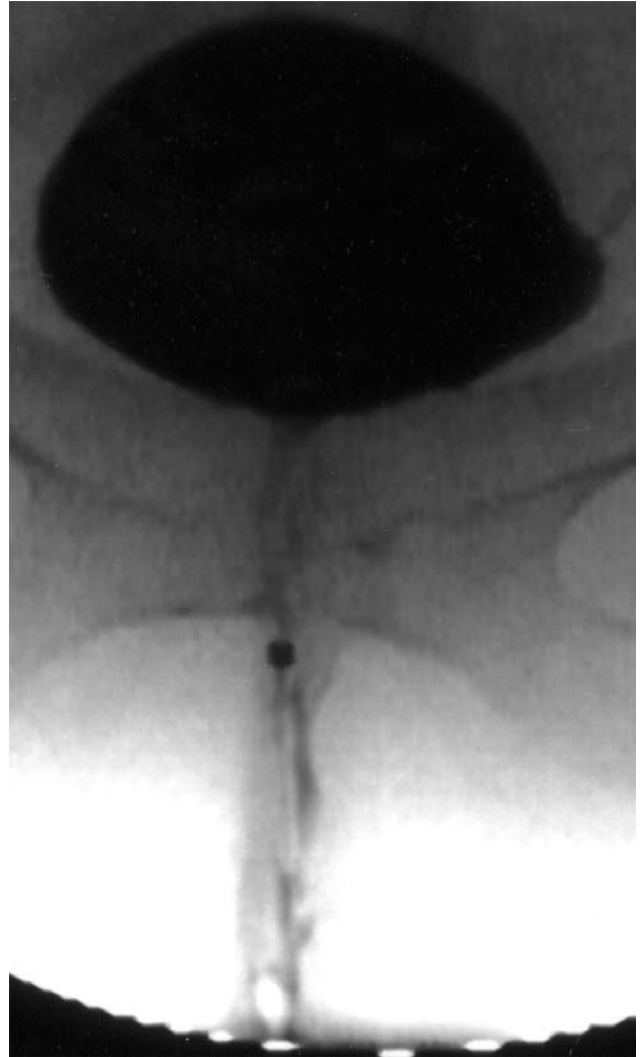


Figure 71.6 Gross continuous leakage after a non-autologous sling procedure. The leakage increased with activity, and also occurred with minimal activity when sitting or supine. The video study clearly shows stress incontinence but there is also a fistula between the bladder neck and the left side of the vagina. This is hard to diagnose as there is coexisting stress incontinence.

autologous fascia sling placed about the proximal urethra is indicated.

STANDARD AUTOLOGOUS FASCIA SLINGS

Patients are placed in adjustable stirrups and given regional or general anesthesia (Figure 71.8). We use appropriate prophylactic antimicrobial agents. A transverse abdominal incision is made and carried down to the rectus fascia which is opened. The sling is taken



Figure 71.7 An 18-year-old woman with a lipomeningocele, stress incontinence, and non-function of the proximal urethra and an areflexic bladder managed by clean intermittent catheterization. An autologous sling was used to close the proximal urethra.

from the inferior leaf of fascia, although one can use the upper leaf if that looks to be better tissue (Figure 71.9A and B). The sling dimensions are 2 cm width at the center tapering to 1 cm or less at each end, and 6–9 cm length. The sling is oversutured at each end with absorbable material and the suture ends are left long (Figure 71.9C).

Depending on the circumstances the next step is variable. For patients who have had a Burch type procedure, or a TVT, where we can see the TVT incisions on the abdominal skin and they are medial, we go lateral to the rectus muscles and enter the retropubic space there through the transversalis fascia on each side. Generally this area is inviolate and blunt, careful dissection clears the bladder off the symphysis, and leads to the endopelvic fascia on either side of the urethra. If the prior procedures are anchored laterally,

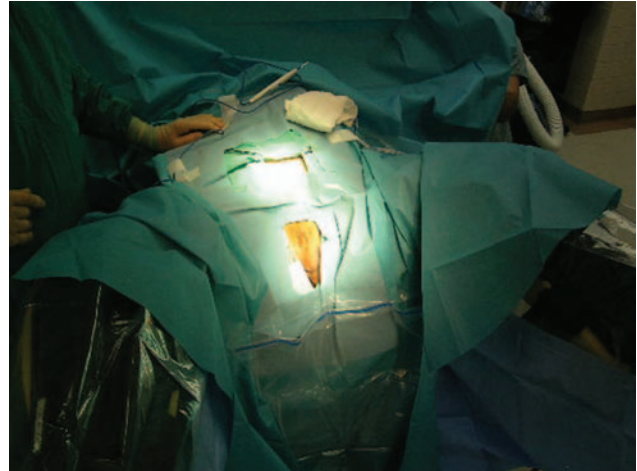


Figure 71.8 Position of the patient for an autologous sling.

for example a TOT, or a cadaveric bone-anchor sling, we would open the rectus muscles in the midline and develop the retropubic space from that vantage point.

In those cases where we need to cross the sling ends over in front of the urethra we would develop the retropubic space through a midline approach. In cases of pelvic fracture and polytrauma, especially where there is diastasis of the symphysis, then a diligent search for a pathway to guide the sling into position on each side is essential. Sometimes this takes quite some time as the peritoneum and its contents are densely adherent to the posterior aspect of the symphysis and the fibrous tissue bridging the diastasis resulting from the pelvic fracture.

Anchoring the sling sutures here is critical and the more lateral one is forced to go to find firm tissue, the less complete the urethral compression will be. If the retropubic space is impenetrable, it is best to not force things but to go to the vaginal part of the dissection and see if that route permits sling positioning.

VAGINAL PART OF THE SURGERY

The legs are flexed more at the hip and a vaginal retractor placed. A Foley catheter is placed and an inverted 'U' shaped incision is made in the vaginal epithelium over the proximal urethra (Figure 71.10A). The flap of vaginal tissue is dissected off the urethra and entry to the plane between the urethra and the vagina is gained (Figure 71.10B). Using the scissors, very gentle spreading dissection is used to just enter the retropubic space through the endopelvic

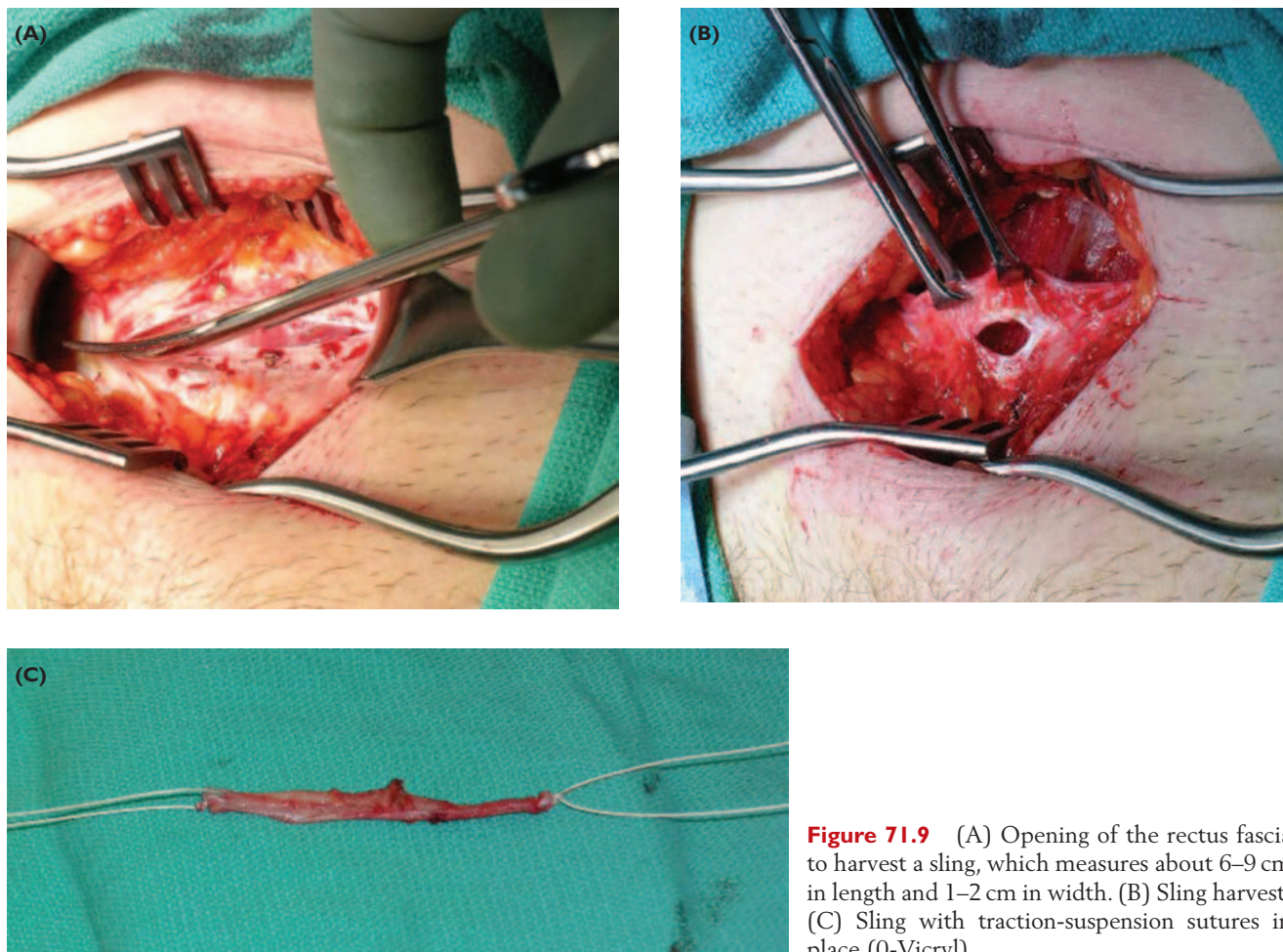


Figure 71.9 (A) Opening of the rectus fascia to harvest a sling, which measures about 6–9 cm in length and 1–2 cm in width. (B) Sling harvest. (C) Sling with traction-suspension sutures in place (0-Vicryl).

fascia. If the pathways from above are already defined passage of the ligature carrier is easy and atraumatic. If not, then we will try to advance the ligature carrier from below. The ligature carrier is placed in the cleft between the urethra and vagina until its leading flat portion is flat on the back of the symphysis (Figure 71.10C). It is then advanced in contact with the symphysis (or if no symphysis the fibrous band) until it emerges from the suprapubic incision. Using this method, one can preload the sling sutures on the passer, or load them after passage when the instrument emerges within the suprapubic incision. One can then pull the sling down by its sutures on one side first, and then, while still loaded with the sutures, the instrument is passed up the other side in the same manner as the first step on the original side (Figure 71.10D). This results in the sling being positioned behind the proximal urethra (Figure 71.10E). After each step, flexible cystoscopy is done with the ligature carriers in place as they are easy to identify if they are in the bladder at any point.

In difficult cases, injury to the bladder is relatively common, but passage of the instrument from below upward is safer in any case where the retropubic space is not open, but frozen. The correct plane along the posterior aspect of the symphysis, or the fibrous band connecting a bony diastasis is easier to enter from below than from above.

SLING TENSION

In cases of pure intrinsic sphincter deficiency identified by videourodynamics, endoscopy, and a leak point pressure, or an upright cystogram at a minimal bladder volume showing an open bladder neck, some tension on the sling is required. A very wide open proximal urethral sphincter as seen in neurologic conditions is best treated by crossing the sling ends over each other in the retropubic space in front of the urethra. This increases the contact of the sling with the open urethra and gives better coaptation. It also avoids over

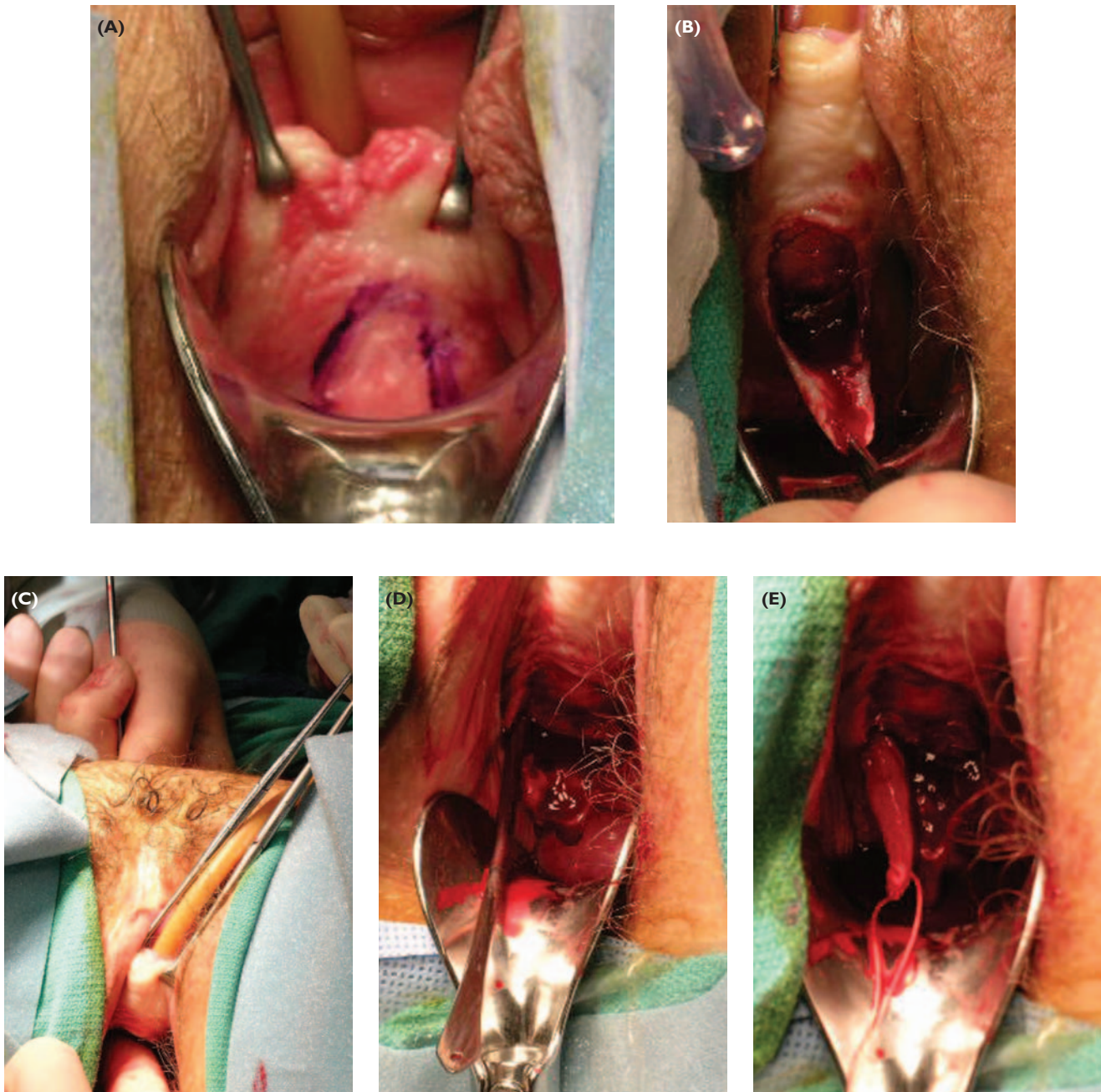


Figure 71.10 (A) Anterior vaginal wall incision marked with blue ink. (B) The vaginal flap developed and the periurethral fascia visualized. (C) A ligature carrier passed (either direction is fine) under bimanual control. (D) Ligature passer in place. The sling sutures will be loaded via the small opening in the blade of the passer. (E) The sling in place behind the proximal urethra. The sling is positioned on the patient's right and the left side will be positioned next.

correction by a standard posterior vector force sling which can make intermittent catheterization very difficult (Figure 71.11).

In acquired proximal sphincter failure, tension can be less but some tension is definitely still required. Adjustment of tension in a supine anesthetized patient, with her legs flexed is an inexact science at best.

POSTOPERATIVE CARE

Most patients can go home the day following surgery. All require intermittent catheterization for an average 8-day period. If 30 days elapse and a patient still requires catheterization, we take the sling down by removing a small segment just underneath the urethra.

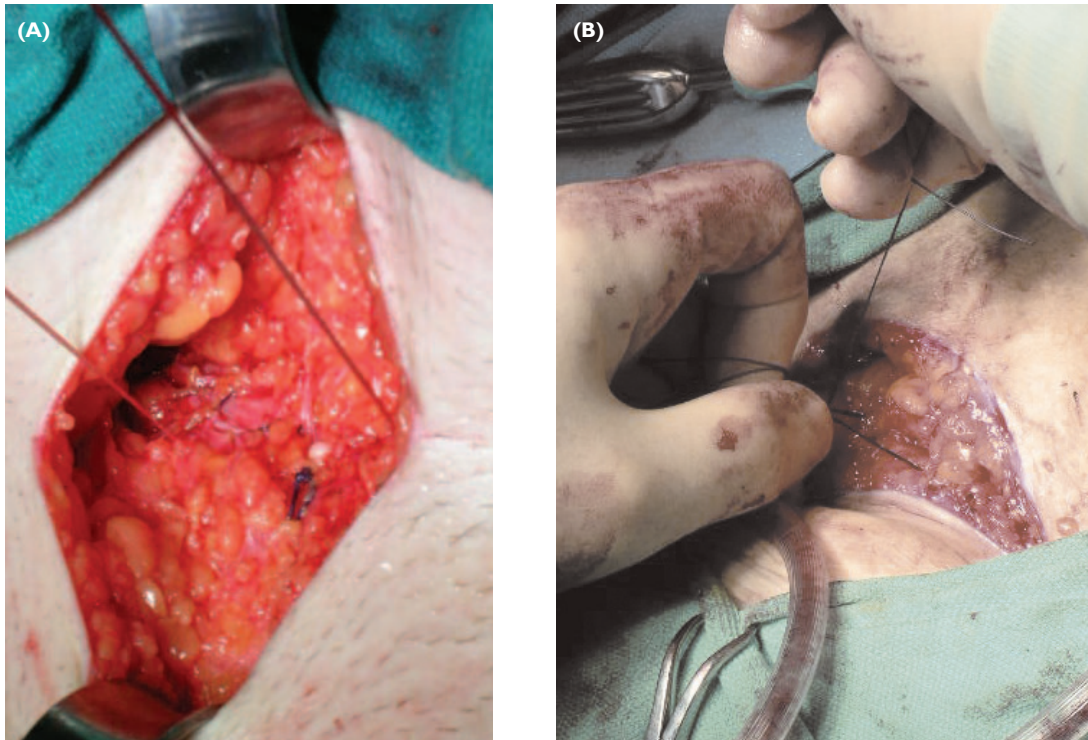


Figure 71.11 Sling sutures passed through the rectus fascia which has been closed.

Doing this early solves problems with overactive bladder dysfunction and urgency and frequency syndromes. On the other hand, slings done in neurogenic vesical dysfunction are under considerable tension and though the bladder may respond, it usually does not and thus, factors other than applied tension may be involved in postoperative voiding dysfunction. Giri et al in Ireland did pelvic magnetic resonance imaging (MRI) studies after sling procedures and were surprised to note hematoma formation was more common than anticipated. This may have something to do with voiding dysfunction or retention.²³

PROBLEMS

Urgency and urge incontinence

Urgency and urge incontinence are common but generally transient. After full emptying is achieved, anticholinergic agents or alpha-blocking agents can be used with good effect. We tend to use alpha-blocking agents as they have fewer side-effects and they are effective for urgency and frequency syndromes. Despite what is written in the literature, the major effect of alpha-blocking agents is on the bladder and not the outlet. These agents are as effective in women as they are in men.

Really severe resistant urgency and frequency suggest obstruction or something in the bladder which does not belong there like a suture or a sling part. If the suspension sutures are Vicryl, and the sling autologous, either or both will disappear with time if you can wait. If not, endoscopic removal with a resectoscope is easy and effective. Flexible endoscopy is essential if patients are unhappy after any kind of sling. We commonly see patients with bladder or urethral erosion who have had symptoms for months but never underwent cystoscopy.

Obstruction

Obstruction is not common but is best dealt with early on. Patients still needing intermittent catheterization after 1 month or those who require strange positions to achieve voiding are obstructed and the sling should be taken down.

Failure

Sling failure occurs when patients are just 'wet' and almost always say they are the same as before the sling. Upright videourodynamics resolves the issue of causation (Figure 71.12). With 300 ml in the bladder, and

no leakage with straining and coughing, this means the sling is satisfactory and the problem is an overactive bladder. Infrequently, the sling appears attached but does not exert enough compression on the urethra. In this regard there is a limit to the force which can be safely applied to a urethra without causing obstruction. In patients who are suffering from neurogenic conditions, managed by intermittent catheterization, this does not matter, but in those with total loss of proximal urethral function who are expecting return of normal voiding after a sling, a posterior vector force sling may not be enough to close the urethra without a very high risk of obstruction. In that case a more circumferential crossed sling may be useful.

Leakage seen on the video study with coughing or straining means the sling is loose, broken, pulled away, and does not work. It is better to find this early and plan the next procedure.

Pain

Pain on one side or another is common until the Vicryl sutures let go as they are absorbed. Patients can get relief by lying down with their legs elevated to take the tension off the sling. Otherwise pain, after the first day or so, is not a big problem with slings.

Bleeding

There are two sources of postoperative vaginal bleeding. The most common is drainage of a vaginal hematoma, and the least common is bleeding from the vaginal suture line. If the latter happens, it is best to see that patient quickly as vaginal suture line bleeding can be excessive and requires a suture. A vaginal hematoma needs no treatment but it is impossible to tell one from the other over the telephone.

Catheterization difficulty

Preoperative instruction in intermittent catheterization is essential but even very well taught women may have trouble when their bladder becomes over distended as the sling gets very tight and the situation is painful. These patients need to be seen, and not sent to a local emergency room or to a visiting nurse. Traumatic catheterization with a very full bladder can penetrate the urethra and expose the sling, which turns a routine problem into a 3-week problem for the patient solved only by chronic catheterization with a

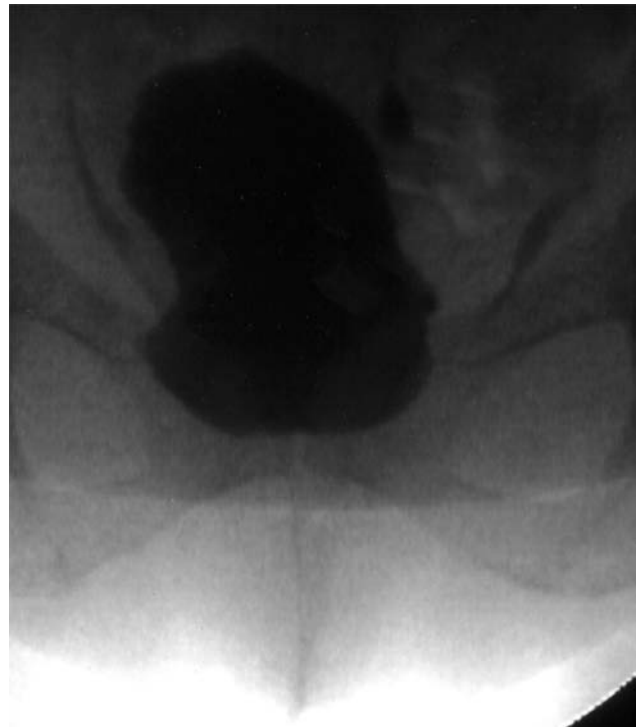


Figure 71.12 Postoperative evaluation of the young woman with an areflexic detrusor and non-functional urethra (see Figure 71.7) treated with an autologous sling. She was occasionally wet at night and while sitting. Videourodynamics show a low compliance bladder with bilateral vesicoureteral reflux and urethral leakage driven by detrusor pressure. This was treated and corrected with medication (an anticholinergic agent, an alpha-blocking agent, and a tricyclic antidepressant). The risk of a sling in a patient with a neurogenic bladder is the bladder's response to the increased urethral resistance.

12 Fr catheter, until the urethra heals. It always heals. Difficult catheterization with a very full bladder requires good lighting, good visibility, a coude catheter (12 Fr), and gentle finger support of the posterior aspect of the urethra to guide the catheter past the sling. One can use a flexible cystoscope to pass a wire if the coude catheter will not negotiate the urethra. In this case, an injury to the urethra, with a false passage, and a visible sling in the depths of the false passage will be quite obvious. In either case leave the small Foley in place until the laceration heals and the sling can no longer be seen. It is then safe to remove it. If there is no visible injury and the problem was inability to catheterize associated with a very full bladder, then we usually just leave a 12 Fr Foley catheter in for a few days as often patients with this problem are afraid it will happen again.

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72 Reconstructive procedures for male-to-female gender reassignment

Carolina R Alvayay and Arnold Melman

INTRODUCTION

Gender identity disorders are characterized by strong and persistent cross-gender identification accompanied by persistent discomfort with one's genetic sex. '*Gender identity*' refers to an individual's self-perception as male or female. The term '*gender dysphoria*' denotes strong and persistent feelings of discomfort with one's genetic sex, the desire to possess the body of the other sex, and the desire to be regarded by others as a member of the other sex. These terms should be distinguished from the term '*sexual orientation*', which refers to erotic attraction to males, females, or both.

Transsexualism was first described by Benjamin in 1953.¹ The Harry Benjamin International Gender Dysphoria Association was founded in 1978 and plays a major role in the research and treatment of transsexualism. In addition, the association publishes the *Standards of Care for Gender Dysphoric Persons*, which provides flexible guidance on the treatment of persons with gender identity disorders. The diagnostic phase, which consists of two stages, differentiates gender dysphoria from other conditions and is the point at which patients are provided with information concerning treatment and surgery. The first part of the diagnostic stage consists of establishing an accurate diagnosis based on the criteria of the *Diagnostic and Statistical Manual of Mental Disorders* of the American Psychiatric Association.² Four criteria must be met for an individual to be diagnosed with gender identity disorder.

- (1) A strong and persistent cross-gender identification, which is the desire to be, or the insistence that one is, of the other sex.
- (2) Evidence of persistent discomfort about one's genetic sex or a sense of inappropriateness in the gender role of that sex.
- (3) The diagnosis is not made if the individual has a concurrent physical intersex condition (e.g. partial androgen insensitivity syndrome or congenital adrenal hyperplasia).

- (4) Evidence of clinically significant distress or impairment in social, occupational, or other important areas of functioning.

The goals of the diagnostic phase, which can last from 6 to 12 months, include diagnosing the patient accurately, as well as eliminating those who are found to have other psychiatric abnormalities. The second stage (also called *real-life experience*) involves the subject taking on the role of the desired sex in everyday activities, both socially and professionally. This period may last from 12 to 18 months, and supportive psychotherapy is mandatory. After the diagnosis of gender identity disorder is confirmed, an endocrinologist evaluates the patient and, if there are no contraindications, hormonal therapy is started. In the male-to-female transsexual, a reversible chemical castration (*suppressive phase*) is first instituted, followed by using female hormones (*substitution phase*) 1 year later. Surgery should be deferred until at least 1 year after starting hormonal treatment and at least 2 years after the first psychological consultation.

OPERATIVE TECHNIQUES

This chapter discusses the various techniques for creation of a new vagina in male-to-female transsexuals. There is general agreement that use of the penile skin inversion with glans clitoroplasty is the surgery of choice for initial vaginoplasty in male-to-female transsexuals. Rectosigmoid neocolpoptosis should be considered only when penile skin inversion has not led to functional results. Estrogen therapy is discontinued 4 weeks before surgery to reduce the risk of deep venous thrombosis and to minimize postoperative tissue swelling. Patients are given a perioperative intravenous antibiotic, such as cefoxitin. Full bowel preparations are given only to patients undergoing rectosigmoid vaginoplasty.

Clitoroplasty

Since 1992, several authors have regarded the pedicled island flap of the glans penis as the standard procedure for clitoroplasty in male-to-female transsexual surgery. Embryologically, the glans penis and clitoris are homologs, and mutual substitution seems to be the logical approach. A neoclitoris improves patient satisfaction, by providing the patient with a sensate clitoris, as well as a more natural appearance. The first description of the construction of a neoclitoris using the reduced glans was by Brown in 1976,³ followed by Rubin in 1980.⁴ While treating these initial series of patients, the incidence of clitoral necrosis was 33% and 46%, respectively. Despite complete clitoral necrosis with subsequent resection, six of seven patients reported ability to achieve orgasm.⁵ Thus, it seems that a clitoris is not essential to orgasm. Regardless, most patients (75%) believe that the creation of a clitoris during surgery is very important for the external appearance of the genitalia and for the ability to achieve an orgasm.⁶ Today, most surgeons who perform clitoroplasty use the dorsal portion of the glans penis with preservation of the dorsal neurovascular pedicle, as described by Eldh.⁷ With this technique the incidence of clitoral necrosis is uncommon, with one in 20 patients experiencing this complication. Rehman and Melman⁸ reported that 90% of patients were capable of orgasm with creation of a dorsal glans neoclitoris.

The penis is characterized by an extensive neural network at the 11 and 1 o'clock positions, and dissection should be carried out directly on top of the tunica albuginea to prevent neuronal injury.⁹ The traditional design involves use of a small triangular segment of the dorsal glans, but Giraldo et al¹⁰ designed a modification that consists of a bilateral dorsolateral coronal flap harvested in the shape of an open lotus flower. The two flaps are approximated one against the other with a central suture line. In addition, the authors advocate using a small flap of the posterior urethral stump to line the vestibulum between the neoclitoris and the new urethral meatus. Giraldo et al¹⁰ advocate this bifid approach to clitoroplasty because the dorsal penile nerves run along the dorsolateral zones of the shaft of the penis, approximately 1.5–2.0 cm distant from the deep dorsal vein (midline). No patients experienced necrosis of the neoclitoris, and all reported ability to achieve orgasm. Based on the same anatomic concept, Perovic et al¹¹ recommend preserving large amounts of the lateral aspects of the glans penis and removing the central erectile tissue. Others prefer to preserve the

entire glans and de-epithelialize three quarters of the glans and place it subcutaneously.¹² Regardless of the method used, the goals of clitoroplasty are to preserve adequate sensation and to reduce the size of the glans so that it more closely resembles a natural clitoris.

Abdominal pedicled penile skin inversion with formation of neoclitoris from glans penis

The preferred method of male-to-female genitoplasty is the inverted penile skin vaginoplasty with creation of a glans clitoroplasty. Use of inverted penile skin to create a neovagina was first described by Granato in 1974.¹³ The inverted penile skin may be used on an abdominal pedicle as an inside-out tube to create a neovagina. The advantages of penile skin flaps include less tendency to contract compared with grafts, local innervation being provided, and the flap being virtually hairless. The major disadvantage of a penile skin flap is that a limited amount of penile skin may be available to create a neovagina of adequate depth and width.

The patient is placed in an exaggerated lithotomy position and a longitudinal incision is made from the median raphe to 1 cm above the anus, and the central tendon is divided. A curved Lowsley retractor is inserted into the bladder to push the prostate forward into view. To create a space for the neovagina, a large plane is developed between the urethra and rectum. If necessary, the levator muscles may be split longitudinally to increase the transverse diameter of the space. The anterior layer of Denonvilliers' fascia is separated from the posterior layer, and dissection is carried down to the peritoneal reflection (Figure 72.1). A penile subcoronal circumferential incision is made, and a tubular dissection of penile skin superficial to Buck's fascia is performed; care should be taken not to injure the dorsal neurovascular bundles. The denuded penis is pulled out of the surrounding skin into the perineal incision. The dorsal neurovascular bundle, which supplies the glans, consists of the dorsal vein and paired dorsal arteries and nerves. Two longitudinal incisions are made lateral along Buck's fascia to free the penile neurovascular bundle carefully; this bundle supplies the future neoclitoris (Figure 72.2). The suspensory ligament of the penis is suture ligated and transected. The paired corpora cavernosum are dissected proximally to the base, resected, and ligated with 0 chromic catgut sutures. Suture ligatures are applied to the branches of the dorsal arteries and veins of the penis.

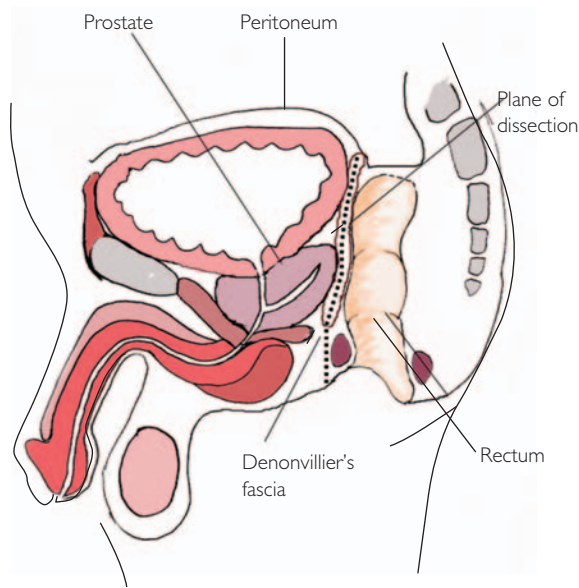


Figure 72.1 Sagittal view of male pelvic anatomy. For creation of the abdominal pedicled penile skin inversion, a plane is developed between the prostate and rectum, and continued within Denonvillier's fascia to the peritoneal reflection.

A bilateral orchiectomy is then performed with high ligation of the spermatic cord at the external inguinal ring. The urethra is dissected from the corpus spongiosum and then divided at its midportion. Then a space is created beneath the abdominal skin up to the level of the umbilicus. The anterior abdominal skin is advanced and sutured to the pubic symphysis using No. 1 non-absorbable polypropylene retention sutures. This step ensures that the penile skin is positioned without tension at the pelvic opening. The penile skin is converted into a full-thickness skin graft by removing all of the subcutaneous tissue. Removal of subcutaneous tissue leaves a very thin layer of skin, which allows for an increase in the width and length of the penile skin, and the denuded penile skin will 'take' faster.¹³ The distal opening of the penile skin is closed with 3-0 chromic catgut suture to form the future neovaginal apex. The penile skin is then inverted over a 60 ml syringe and is placed into the pelvic opening. A suture is placed at the 6 o'clock position of the neovagina anchoring it to the perineum. At the appropriate positions, two small incisions are made for the urethral and clitoral openings. The urethra is trimmed, spatulated, and sutured to the lower opening using interrupted 3-0 chromic catgut. The glans is reduced to an appropriate clitoral size and is brought into the more cephalad opening, taking care not to kink the underlying neurovascular bundle, and sutured in place with 3-0 polyglactin

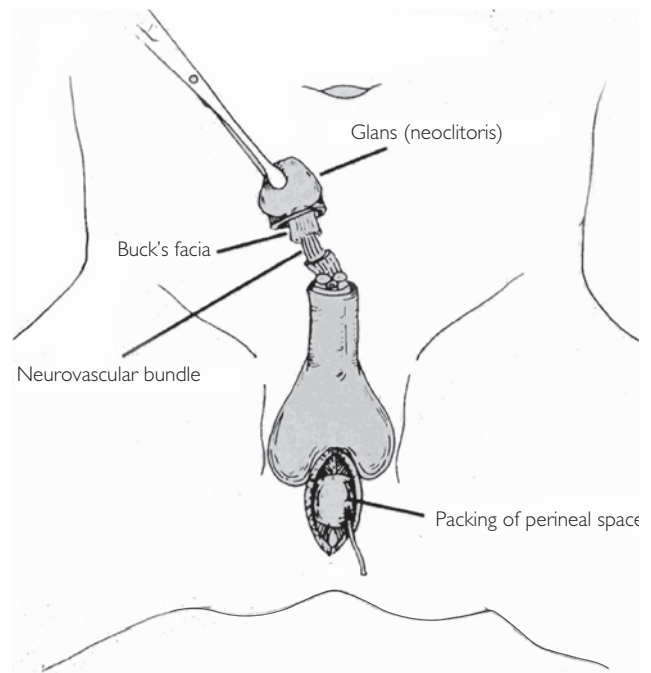


Figure 72.2 Inverted penile skin vaginoplasty with glans clitoroplasty. The pelvic opening is packed with gauze during dissection of the dorsal neurovascular bundle.

910. The scrotal skin is trimmed, if necessary, and is used to construct labia majora using 3-0 chromic catgut (Figure 72.3). An indwelling Foley catheter is placed into the neourethra. A 16 cm inflatable vaginal stent is placed into the neovagina and filled with approximately 120 ml of air. It is important to have adequate coaptation of the raw surfaces of the neovaginal skin graft to the surrounding tissues to facilitate prompt adhesion. In addition, loose packing may result in hematoma formation with increased risk of flap necrosis. Penrose drains are placed in the perineum through separate stab incisions. A pressure dressing using gauze fluffs and adhesive tape is placed over the entire surgical site and perineal area.⁸ The patient is kept on bedrest for 3–5 days after surgery. There is some variability, depending on surgeon preference, regarding the timing of removal of the drains and dressings. They may be removed after 48 hours or as late as 7 days after surgery. The patients are instructed to keep the neovagina patent by daily dilatation with a vaginal dilator. The Foley catheter and vaginal stent are left in place for 7 days. Melman and Rehman⁸ reported that nine of ten patients could achieve orgasm most of the time. Two of their patients experienced partial necrosis of the neoclitoris, with one patient being unable to achieve orgasm.⁸



Figure 72.3 Photograph of external genitalia 3 months after abdominal pedicled penile skin inversion with formation of the neoclitoris from glans penis.

Use of tissue expansion in male-to-female gender reassignment

If there is an insufficient amount of skin to create an adequate neovagina, another technique that may be used is tissue expansion. Other methods to address this problem include a combined penile-scrotal skin technique, adding a split-thickness graft to the inverted penile skin, or using an intestinal segment to create the neovagina. Use of a split-thickness graft has the disadvantages of donor site scarring and possible stenosis at the graft–penile skin suture line that is placed deep within the neovaginal space. Krege et al¹² reported that of ten patients who underwent initial vaginoplasty with penile skin augmented with free-skin mesh graft, three patients ultimately required ileal augmentation because of scarring at the suture line. The advantages and disadvantages of intestinal segments and penile-scrotal skin flaps are discussed below.

This method involves expanding the penile skin with a tissue expander as a preliminary stage. The surgery is performed on an ambulatory basis a minimum of 6 weeks before the planned gender reassignment surgery. The tissue expander can be inserted by means of an infrascrotal incision or through a longitudinal lower inguinal or infrapubic incision. We prefer a lower inguinal incision because it avoids having a scar at the introitus of the future neovagina. A plane is created with blunt dissection between the dartos and Buck's fascia along the entire length of the penis stopping subcoronally. Care must be taken not to dissect over the urethra. If the tissue expander is filled over the corpus spongiosum, then urinary outflow may be obstructed.

A rectangular tissue expander (4 × 6 cm 100 ml or 5.0 × 8.5 cm 200 ml; McGhan Medical Corp, Santa Barbara, CA; Coloplast, Inc., Goeta, CA) is placed in the space. Then, a space for the injection port is created with blunt dissection in a subcutaneous pocket over the inguinal canal. The wound is irrigated with antibiotic solution and the wounds are closed with absorbable sutures. The penis is wrapped with Coban™ self-adherent dressing (3M Healthcare, St Paul, MN) for 3–4 days. After a 7-day recovery period, weekly injections are begun. The volume of saline injected depends on the size of the expander used and the pain threshold of the patient. The injections are continued until the expanded penile skin is of sufficient surface area to create an adequate neovagina using the standard penile inversion technique. At the time of surgery, the tissue expander slides out of the pseudocapsular pocket and minimizes the dissection needed to free the penile skin. The thickened pseudocapsule does make dissection of the dorsal neurovascular bundle of the penis more difficult. This method provides a safe and effective way to increase the amount of skin available to create a functional neovagina in male-to-female transsexual patients.

Penile-scrotal skin flaps

If there is a limited amount of penile skin, then it can be augmented with a posteriorly based scrotal skin flap. However, this technique will introduce hair-bearing skin at the posterior vagina if no preoperative depilation has been performed. The pedicled penile skin tube is split open to form a rectangular flap that is augmented by a rectangular, posteriorly pedicled scrotal skin flap. The steps of the operation are similar to those described above for the inverted penile skin technique with the following changes. When the need for a scrotal flap is anticipated, an inverted 'U' shaped incision should be extended high up the scrotum and the base should be to the level of the ischial tuberosities. The scrotal flap is raised and reflected inferiorly to expose the bulbar urethra. The edges of the scrotal and penile skin flaps are then sutured together with 3-0 absorbable suture. The result is a tube that can be invaginated into the pelvic tunnel. The neovagina is held in place with stiff foam packing or a vaginal stent.⁷ Creation of the neoclitoris and neourethra are the same as the techniques described above.

The reported complications in 20 patients after penoscrotal skin flap neovagina with glans clitoroplasty⁷ were rectovaginal fistula ($n = 1$), partial necrosis of flap ($n = 2$), partial necrosis of glans with

subsequent loss of clitoral sensation ($n = 1$), strictures of the urethral meatus ($n = 3$), and excess urethral stump/spongiosum remnant ($n = 2$). Most patients (19/20) had good clitoral sensation and could achieve orgasm. Hage et al¹⁴ noted that after the penoscrotal technique some patients experienced an obliterating posterior skin fold that subsequently required a secondary surgery. To prevent this, the authors recommend that the perineoscrotal flap be dissected up to 2 cm from the anal ring.

Alternatively, an inverted 'Y' shaped incision can be used creating a triangular perineoscrotal flap that is sutured to the inverted penile skin to form the posterior wall of the neovagina.¹⁵ The authors advocate keeping the dimensions of the perineoscrotal flap to a minimum to reduce the risk of intravaginal hair growth. Karim et al¹⁵ reported favorable results in 200 patients who underwent genitoplasty by this technique. Introital stenosis was the most common postoperative complication, seen in 5% ($n = 10$) of patients. In addition, they noted seven superficial infections, seven urethral strictures, one clitoral necrosis, one rectovaginal fistula, and two patients with obliteration of neovagina requiring rectosigmoid reconstruction.

It is important to shorten the urethra adequately so that the urinary stream is directed downward. Also, the spongiosum tissue should be stripped as much as possible from the urethra to avoid painful swelling when the patient is sexually stimulated.

Vaginoplasty using penile skin and urethral flap

Perovic et al¹¹ reported a combined inverted penile skin and a urethral flap to create a neovagina in 89 male-to-female transsexual patients. The initial dissection is similar to that described above, except that the pendulous urethra and entire glans penis are incorporated into the reconstruction. The glans penis is divided into two parts, ventral and dorsal. The ventral half of the glans remains attached to the urethra and is used to form a neocervix at the base of the new vagina. The dorsal glans with its intact neurovascular bundle is sutured into a conical shape to form the neoclitoris. The urethra is spatulated and the penile skin is incised on the dorsal aspect and the two are sutured together to form a tube. The tube, consisting of penile skin and urethral flap, is then inverted in the usual fashion to form the neovagina. In addition, the authors recommend fixing the neovagina to the sacrospinous ligament, usually on the right, to prevent prolapse. The

sacrospinous ligament is palpated between the ischial spine and coccyx, and a long-handled Deschamps ligature carrier is used to pierce the ligament medially to the ischial spine. Care must be taken not to injure the nearby pudendal nerve and vessels during vaginopexy. The advantages of incorporating a urethral flap into the vaginal construction are that it allows for a wider introitus, provides moisture and sensitivity to the neovagina, and the pseudocervix made from the ventral glans contributes to sensitivity at the neovaginal base. Of patients 80% were satisfied with the surface moisture of the neovagina. Six months after surgery, 79% of patients were capable of normal sexual intercourse. Complications included one rectovaginal fistula, stenosis of introitus in six patients (6.7%), urethral prolapse in two patients which was easily resolved by simple excision, and posterior vaginal wall rupture during intercourse in one patient. Also, there were two patients who had vaginal shrinkage attributed to vaginopexy under high tension, and these patients underwent rectosigmoid vaginoplasty.¹¹

PEDICLED INTESTINAL TRANSPLANT FOR VAGINOPLASTY

A pedicled intestinal transplant is thought to be the best choice for patients who have had an unfavorable previous vaginoplasty. The advantages of using rectosigmoid transplant are that its length, texture, and appearance are similar to a natural vagina. It is the only method that provides a vaginal lining with natural lubrication that is resistant to trauma. However, the production of mucus may lead to excessive discharge. Reported disadvantages of using an intestinal transplant are the need for abdominal surgery, diversion colitis (inflammation in the bypassed tissue secondary to diversion of fecal stream), introital stenosis, intestinal obstruction, and mucocele.

Rectosigmoid vaginoplasty

Rectosigmoid colon vaginoplasty was originally developed for female patients with vaginal agenesis (Mayer-Rokitansky-Kuster-Hauser syndrome) and in cases of vaginal loss secondary to gynecologic cancer. Today, most surgeons performing reconstructive vaginal surgery in the pediatric and female population favor a technique using a pedicled isolated sigmoid colon segment.¹⁶ The first use of an intestinal transplant for vaginoplasty in transsexuals was in 1974, when Markland and Hastings¹⁷ used cecum

in five patients. Subsequently, they began to use sigmoid because the sigmoid mesocolon is longer and more easily mobilized than the cecum and is able to reach the perineum more easily.¹⁸ Minimizing tension on the mesenteric blood supply lessens the chance of ischemic necrosis. In addition, the neovagina is more sensitive secondary to the rectal component of the transplant.

Rectosigmoid neocolpopoiesis should be considered in male-to-female transsexuals only when penile skin inversion is not possible or has not led to functional results. The most common reasons to consider rectosigmoid vaginoplasty after penile skin inversion are severe neovaginal stenosis or rectovaginal fistula.^{19,20} The use of sigmoid colon has several advantages: (1) length and texture of sigmoid vagina is more natural; (2) stenosis of introitus is rare; (3) it is the only method that, secondary to sigmoid mucus production, provides natural lubrication and thereby facilitates sexual intercourse; (4) sigmoid serosa provides well vascularized tissue to place over the repair of a rectovaginal fistula;^{19,21} and (5) risk of flap necrosis or lack of graft take is minimal.²²

The major disadvantage of using pedicled intestinal transplant for vaginoplasty is that it involves major surgery with an abdominal incision, which may be aesthetically displeasing to the patient, and intestinal resection and reanastomosis. Karim et al²⁰ reported one patient in whom peritonitis developed secondary to leakage from intercolonic anastomosis with subsequent necrosis of rectosigmoid neovagina.

Rectosigmoid vaginoplasty is performed through a combined abdominal, usually modified Pfannenstiel incision, and perineal approach. After mobilization of the descending colon, a 15–20 cm segment of rectosigmoid colon is chosen. The rectosigmoid mesocolon is divided, ensuring preservation of a sigmoid artery branch from the inferior mesenteric artery (IMA) and vascular arcade for the transplant (Figure 72.4). The superior rectal artery is left intact to supply the remaining rectal stump. The vulvar vestibulum is opened using lateral longitudinal incisions, preserving all remaining skin from previous penile inversion vaginoplasty. A cavity between the bladder and the rectum is dissected; this is done carefully to avoid entering the rectum or urethra, because scarring may be extensive from previous surgery and complications. Additional width of the cavity may be created by bilateral incision of the superficial layers of the levator ani muscles. The peritoneum is incised and the cephalad end of the sigmoid transplant is brought down to the perineum without kinking of the vascular pedicle (Figure 72.5). Continuity of the intestinal tract is restored and the abdominal incision is closed.

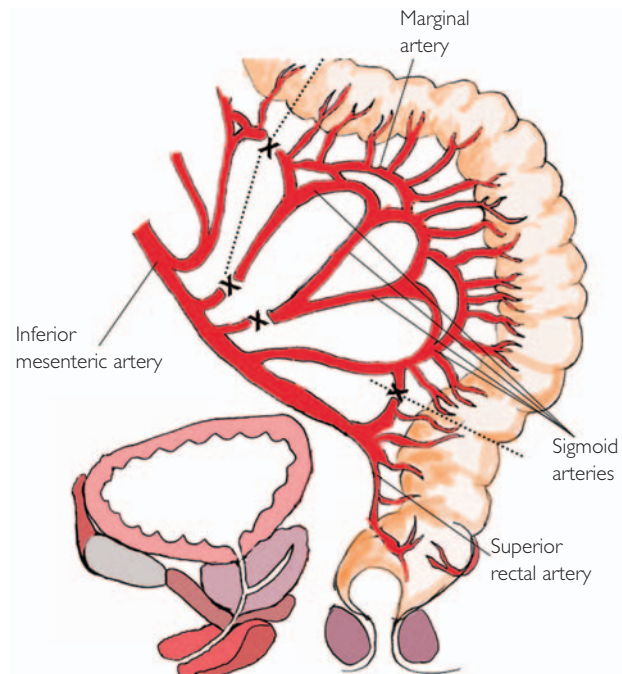


Figure 72.4 Rectosigmoid vaginoplasty. A 15–20 cm segment of the rectosigmoid colon is chosen and the mesocolon is divided with preservation of the distal sigmoid artery branch of the inferior mesenteric artery. The more proximal sigmoid branches are ligated as shown.

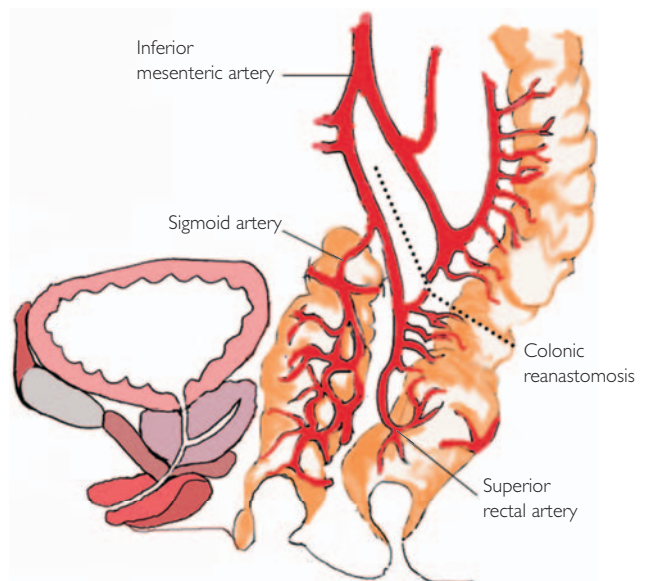


Figure 72.5 Rectosigmoid vaginoplasty. The sigmoid colon is reversed so that the cephalad end is brought down to the perineal incision and anastomosed to the remains of the prior penile skin inversion.

Introital stenosis is still of concern with rectosigmoid vaginoplasty. There are various surgical methods

that can be used to try to prevent this complication. Dalton¹⁹ recommends that the mucocutaneous junction repair should be oval and not round to prevent stenosis. Karim et al²⁰ recommend preserving all remaining skin of the previous penile skin inversion, incising it bilaterally in a longitudinal fashion, and then suturing the rectosigmoid mucosa to the skin in an interdigital fashion. Other authors have suggested using bilateral Z-plasties at the mucocutaneous junction to prevent the purse string effect of a circular scar and thus minimizing the risk of introital stenosis.²³ Continued regular dilatation of the introitus is still recommended until the patient becomes sexually active.

The original method of mobilizing the sigmoid, as described by Markland and Hastings,¹⁸ involved preservation of the distal long sigmoid branch of the inferior mesenteric artery as the primary blood supply and division of the more proximal branches. The sigmoid colon is reversed so that the cephalad portion is brought down for the perineal-cutaneous anastomosis. Franz²³ reported that, if additional length is required for the sigmoid transplant to reach the perineum, the IMA can be ligated safely. The IMA first is test-clamped, and subsequently ligated, below the left colic branch. The sigmoid vagina receives sufficient retrograde blood flow from the middle and inferior rectal arterial systems. This technique was performed in 13 patients with no necrosis of the sigmoid neovagina reported.

Long-term results after rectosigmoid vaginoplasty are excellent. Kwun et al²¹ reported results of 36 patients who were followed up for more than 1 year. Of these, 28 patients were male-to-female transsexuals who underwent rectosigmoid vaginoplasty. During the first 3 postoperative months, excessive mucus discharge was common but decreased dramatically, with only 8.3% (three patients) requiring pads for continued excess mucus discharge. The most common postoperative problem was constipation in 13.9%, which improved naturally over the first postoperative year. Also, 5.6% complained of periumbilical pain during intercourse. Two patients had difficulties with urination and required surgical revision of the urethra. No patients experienced vaginal stenosis, and 88.9% were able to achieve orgasm. The longest reported follow-up of sigmoid colon vaginal reconstruction was a mean of 6 years by Parsons et al¹⁶ in 28 patients who underwent surgery in adolescence for a variety of congenital vaginal abnormalities. The authors reported a 14% rate of introital stenosis, all noted within 4 weeks of surgery. All patients responded well to initial dilatation

under anesthesia followed by regular self-dilatation protocol. Additional complications included mucosal prolapse in 14%, partial small bowel obstruction in 7%, and perineal wound hematoma and superficial wound infection in 2%. Most (88%) patients were heterosexually active and none reported dyspareunia, excessive mucus discharge, or clinical symptoms of diversion colitis. Primary sigmoid adenocarcinoma in neovaginas has been reported, but this is very rare. It is recommended that patients undergo routine vaginoscopy in addition to standard colonoscopy for colon cancer screening. With the widespread acceptance of laparoscopically assisted surgery, this technology has been applied to secondary rectosigmoid vaginoplasty. The laparotomy incision used to harvest the sigmoid transplant is the origin of short-term morbidity and a major impediment to good cosmesis, which is particularly important to this patient population. Generally, techniques for laparoscopically assisted bowel resection have been limited to laparoscopic mobilization followed by delivery of bowel through a small modified Pfannenstiel incision to transect the sigmoid and to restore the bowel continuity extra-abdominally. A total laparoscopic rectosigmoid vaginoplasty was reported by Maas et al²⁴ thereby avoiding the morbidity associated with an abdominal incision. After dissection of the neovaginal canal and opening of the peritoneum, a curved intraluminal stapler is introduced intra-abdominally. Gasless abdominal elevation is used during this phase. A staple anvil is inserted into the proximal colon and is secured with a purse string absorbable suture. Then, the shaft of the stapling device is passed transanally up to the level of the distal rectal stump. The shaft of the anvil is grasped and the instrument is fired to give a circular anastomosis. The rectosigmoid transplant is delivered through the perineal incision and anastomosed to the remains of the penile skin inversion. This technique was reported in three patients with satisfactory sexual and cosmetic results. In addition, patients experienced decreased analgesic requirements and earlier mobilization.

Ileal vaginoplasty

Use of ileum in vaginal reconstruction has been described, but reports are rare. Because of its small diameter and short mesentery, use of ileum is more challenging, and isolation of long segments is necessary to reach the perineum without tension. Despite these challenges, Trombetta et al²² provided the first application of the Monti channel, which involves use

of transversely tubularized bowel segments to create continent urinary diversions, to vaginoplasty. Five male-to-female transsexuals underwent ileal vaginal replacement for neovaginal stenosis after previous gender surgery. A 12 cm segment of ileum was isolated using the standard transillumination technique. The isolated segment first was detubularized and then was retubularized transversely and the proximal end was closed with two layers of absorbable suture. Most patients had a normal distal vagina, but if additional length was needed, then two 12 cm segments of ileum were harvested and attached. A tension-free anastomosis was sutured between the vaginal conduit and the perineum with interrupted 3-0 Monocryl (Ethicon, Inc, USA). An inflatable silicon vaginal stent was placed in the vaginal cavity for 7 days. All patients had transient vaginal discharge which resolved within 6 months. At a median follow-up of 18 months, all patients were sexually active, none reported dyspareunia and no ileal-introital stenosis was observed. Although good outcomes have been reported, ileal vaginoplasty in the male-to-female transsexual has been carried out in a very small group of patients with short follow-up. Despite this, dehiscence, necrosis, and late complications such as stenosis and perforation have never been reported with the Monti channel.²⁵ The reported advantages of ileum over rectosigmoid transplant in vaginoplasty include lower mucus production, decreased risk of colitis, and that the urologist is more familiar with the use of ileum in reconstructive surgery.²² In addition, these authors have described successful laparoscopic mobilization and creation of the ileal neovagina through a small transverse right incision.²⁶

SECONDARY SURGICAL CORRECTIONS IN MALE-TO-FEMALE TRANSSEXUALS

The clitoral prepuce and the labia minora remain among the most difficult structures to construct and the ideal method of construction has not yet been achieved. The incidence of secondary corrections after vaginoplasty by inversion of penile skin and triangular perineoscrotal flap was reported by Hage et al¹⁴ to be 22% (86/390 patients).

A common secondary correction is re-creation of the anterior commissure covering the neoclitoris, which often is exposed excessively when a penile skin flap is used (Figure 72.3). This is usually performed with simple excision of intervening tissue or with a double opposing Z-plasty (Figure 72.6). The medial



Figure 72.6 Incision for double opposing Z-plasty to create anterior commissure over neoclitoris.



Figure 72.7 Medial legs of Z-plasty have been joined to obtain a more natural appearing coverage of the anterior aspect of the vulva and to create a clitoral hood.

legs of both Z-plasties may be joined in the midline to obtain optimal closure of the anterior aspect of the vulva and to create a clitoral hood¹⁴ (Figure 72.7). Because of the risk of reduction of perfusion in the inverted penile skin flap, it is advised not to do this as part of the primary genitoplasty.

Some patients request secondary construction of labia minora. This can be accomplished by taking longitudinal skin flaps dissected from the medial aspect

of both labia majora. Care is taken not to injure the vascular supply within the medial pedicle. The posterior half of the flap is folded to cover the lateral raw surface of the anterior flap and is sutured with 6-0 Monocryl. Then, the donor site is closed.¹⁴

Some patients report narrowing of vagina and pain during sexual arousal, and this is the result of incomplete resection of erectile tissue at the time of initial sex reassignment surgery. Total removal of all erectile tissue results in a very low incidence (0.9%) of this complication, but secondary strictures of the urethral wall are seen in 6% (7/115) of patients. Therefore, Karim et al²⁷ recommend that a very thin layer of spongoid tissue be left behind on the urethral wall. Although some authors recommend complete resection of all corporal cavernosal tissue, Laub page 17 (commentary in reference 27), recommends that the cavernosa be resected only to the level of the crus because most of his patients report that maximum erotic stimulation occurs in the two remaining corpora along the pubic rami.

OUTCOMES

The most common complication after male-to-female vaginoplasty is stenosis of the neovagina. Most cases of vaginal stenosis are observed in patients who are non-compliant with vaginal dilatation immediately postoperatively and even years later during periods of decreased coitus.^{5,28} Neovaginal stenosis can be treated with dilatation, Z-plasty, or intestinal transplant in severe cases. Stenosis is less common with rectosigmoid vaginoplasty, but even in these patients it is more common if there is a history of prior stenosis after penile inversion. Hage et al¹⁴ reported the rate of redo vaginoplasty to be 1.8% (7/390 patients). Rectovaginal fistula is a possible complication of male-to-female vaginoplasty with a highly variable incidence reported in the literature of 0–15%.^{5,28,29} To avoid this complication, it is critical to develop the pelvic cavity carefully to avoid injury to the rectum.

One published study directly compared results of using only inverted penile skin with combined penile-scrotal flaps. The cosmetic result was found to be better in the group that underwent reconstruction with only penile skin because 54% of patients in the other group experienced prolapse of scrotal skin. The depth and width of the neovagina was found to be better in the group that underwent combined penile-scrotal skin flap vaginoplasty. The incidence of neovaginal stenosis was higher in the penile skin only cohort, but lack of

compliance with dilatation was a confounding factor, noted in four of five patients with stenosis.²⁹

Other less common complications include urethral stenosis, misdirected urinary stream, vaginal prolapse, excess vaginal hair, intraoperative rectal injury, and residual erectile tissue, which results in pain and vaginal stenosis with sexual arousal. Surprisingly, most reported surgical complications were not associated with a lower overall satisfaction. In a review of 232 male-to-female patients who underwent penile inversion vaginoplasty with glans clitoroplasty, there was no consistent evidence that the quality of surgical results affected patient satisfaction. Also, no patient consistently regretted having undergone sex reassignment surgery.^{6,30} Other data suggest that overall sexual adjustment closely tracks the outcome of genital surgery.⁶ After surgery, most male-to-female patients demonstrate marked improvement in their psychosocial status. Stein et al²⁸ reported a noted decrease in suicidal ideation and complete elimination of suicidal gestures. This is a marked improvement considering three of ten patients in the cohort reported at least one prior suicide attempt and seven of ten patients admitted to suicidal ideation before surgery. Despite the evidence that most patients (75%) report an improvement in their emotional problems and quality of life, a significant number (25%) found difficulty in how to live their lives as females, given that they had obviously not had the benefit of life-long socialization.⁶ Therefore, it is recommended that transgender patients continue with psychotherapy postoperatively so that they can live their lives more fully as females.

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73 Feminizing genitoplasty and correction of cloacal anomalies

Jeffrey A Leslie and Richard C Rink

INTRODUCTION

Management of disorders of sexual differentiation (DSD) such as the pure urogenital sinus (UGS) with or without virilization and cloacal anomalies represent some of the most daunting tasks a reconstructive surgeon may face. The surgical aspects alone can be quite challenging, in addition to the psychological and social issues which are often present. Genital reconstruction for DSD remains a very controversial area. While this chapter focuses on the surgical management of these uncommon conditions, the urologist involved in the care of these children must be keenly aware of these controversies. Most importantly, we strongly feel that the families and other physicians involved should actively participate in the decision-making process regarding reconstructive procedures. A multidisciplinary approach is essential, including a urologist, endocrinologist, psychologist, and neonatologist. The discussion must include both the pros and cons of genital reconstruction, and the parents should be provided with access to national advocacy organizations both for and against such surgery in childhood, such as the Congenital Adrenal Hyperplasia Research Education and Support (CARES) group and the Intersex Society of North America (ISNA). It is beyond the scope of this chapter to fully discuss the myriad controversies regarding childhood genital surgery, but it is clear that further studies are warranted. The remainder of this chapter should be interpreted in the context in which a multidisciplinary team and the family agree to proceed with surgery after considering all of the issues involved.

CLASSIFICATION OF UROGENITAL SINUS AND CLOACAL ANOMALIES

Persistent UGS anomalies occur in a spectrum, and therefore evaluation and management must be tailored accordingly. In UGS abnormalities, there is a persistent communication of the vagina with the urinary tract, but the communication may occur anywhere from the bladder to the urethral meatus. Fortunately,

the majority occur within the mid- to distal portion of the urethra. The two structures join and exit on the perineum as a single common UGS channel.

There are three types of persistent UGS. The most commonly type occurs in genital ambiguity states, usually with congenital adrenal hyperplasia (CAH). It can also occur as a pure UGS with normal external genitalia. In persistent cloacal anomalies, there is the added complexity of rectal involvement, with all three systems – genital, urinary, and rectal – exiting via a single perineal opening (Figure 73.1). We strongly believe that the confluence location in relation to the bladder neck is a far more critical factor in surgical management and outcome, than the length of the common channel (confluence to meatus).

EVALUATION

UGS abnormalities are most often seen in DSD, usually associated with CAH. Initial management must focus on making an accurate diagnosis to allow proper gender identification. Genetic sex determination (rapid karyotyping of cultured peripheral leukocytes) and a multidisciplinary evaluation can usually be completed within 48 hours, and naming of the child should be postponed until a conference with the family and the gender assignment team can be arranged.

Cloacal anomalies are a much more complex problem, but are fortunately less common than UGS anomalies. Some children with these anomalies may also have a prominent phallic structure, requiring a similar evaluation for a DSD.

HISTORY AND PHYSICAL EXAMINATION

The history and examination of the child with genital ambiguity are extremely helpful and can often lead to the diagnosis. It is critical to determine whether the mother ingested any medications during pregnancy, especially androgenic hormones. History of a prior



Figure 73.1 (A) Urogenital sinus anatomy. Vagina and urethra join and exit as a common channel. (B) Cloacal anatomy. Rectum also joins the vagina and urethra to exit as a common channel. IUSM Medical Illustration Department. All rights reserved. Reprinted with permission.

neonatal death or sibling with fluid or electrolyte abnormalities can lead to a diagnosis of CAH. Family history of abnormal pubertal development should also be sought. A general evaluation of the health of the child, presence of abnormal facies, hypertension, or dehydration should be determined. Abdominal examination may reveal a suprapubic mass due to bladder distention, hydrometrocolpos, or both. Hydrometrocolpos is frequently an initial sign and is often the only early finding in pure UGS abnormalities.

In cloacal anomalies, abdominal distention may be severe due to bladder or intestinal distention with or without hydrometrocolpos. Acidosis may develop as urine enters the rectum. The lower part of the back should always be examined to identify vertebral anomalies, which can be associated with UGS anomalies and are very common with cloacal anomalies. Features commonly seen include a sacral dimple, hair patch, abnormally pigmented area, abnormal buttock crease, or flattened buttocks (sacral agenesis).

Genital examination should include notation of the size of the phallus, consistency of the erectile bodies, and curvature. Gonads should be sought and if located, size and position should be documented. If both gonads are descended, it is extremely unlikely that a 46,XX karyotype will be found. The labioscrotal folds should be examined for their relationship to the phallus and rectum, as well as for the degree of fusion. Increased pigmentation of the labioscrotal folds and areola may be seen in some cases of CAH as a result of increased levels of melanocyte-stimulating hormone. In UGS anomalies, the location of the anus should be noted, as anterior displacement may be present. A gentle rectal examination may reveal presence of a cervix.

In the child with a persistent cloaca, a single perineal orifice is present and the appearance of the external genitalia can vary considerably. In some instances, an enlarged phallic structure is present, giving the genitalia a more ambiguous appearance. The single perineal opening may exit what appears to be a normal vaginal introitus, or it may extend to the tip of a phallic structure.

Cloacal anomalies are associated with a high incidence of related anomalies in other organ systems, including renal, bladder (duplication), and uterovaginal (duplication or septation). Additionally cardiovascular, central nervous, respiratory, and vertebral anomalies are not uncommon. Many patients with cloacal anomalies have the VACTERL association (vertebral abnormalities, anal atresia, cardiac abnormalities, tracheoesophageal fistula and/or esophageal atresia, renal agenesis and dysplasia, and limb defects).

RADIOGRAPHIC AND ENDOSCOPIC EVALUATION

Paramount to the surgical reconstruction of the UGS or cloaca is the understanding of the anatomy of each child preoperatively. The length of the common UGS, location of the vaginal confluence and its proximity to the bladder neck, the size and number of vaginas, and presence of a cervix must be defined by radiographic and endoscopic evaluation. The vaginal confluence with the urinary tract occurs in a continuum from the bladder to the urethral meatus and must be determined prior to reconstruction.

Ultrasonography of the kidneys and pelvic structures should be performed, as well as genitography, with filling of the entire bladder, vagina, and common sinus. In cloacal anomalies, the rectal confluence should be opacified as well, if possible. The most helpful study, however, is endoscopy. In children with CAH, this can usually be performed at the time of reconstruction, unless the vaginal confluence cannot be assessed on genitography or in more complex cases. When the vagina cannot be opacified on genitography, a small ureteral catheter can usually be passed into the vagina endoscopically, to allow fluoroscopic evaluation of the size and position of the vagina relative to the common sinus and bladder neck. In severely masculinized girls, the vagina is often very proximal, entering into a verumontanum-like structure. Rarely, gonadal biopsy is necessary, which can usually be performed laparoscopically. This should only be required when the findings would influence the gender of rearing. If deemed necessary, a deep incision should be made into the gonad, as the ovarian component of an ovo-testis may completely surround the testicular component or be located at the poles.

Children with pure UGS anomalies or cloacal anomalies should undergo echocardiography and magnetic resonance imaging (MRI) of the lumbosacral spine and pelvis. Because of the complexity of the anatomy and the frequency of hydrometrocolpos, a child with a cloacal anomaly often needs endoscopy early as a separate procedure to decompress the vagina and bladder and to define the anatomy. Entry into the bladder can be very difficult, as the distended vagina (or vaginas) may displace the bladder very anteriorly. For this reason, the vagina should always be emptied first. Identification of the rectal fistula can also be difficult, but once located, it should be irrigated through the scope and distal limb of the colostomy.

RECONSTRUCTIVE SURGERY FOR THE UROGENITAL SINUS

Timing of genital surgery

Children born with a UGS (CAH most commonly) associated with genital ambiguity usually have clitoral hypertrophy, fusion of the labia with absence of the labia minora, as well as a common UGS. Therefore, genital reconstruction involves three steps: clitoroplasty, labioplasty, and vaginoplasty. As mentioned in the Introduction, childhood genital surgery for DSD has been challenged by some intersex advocacy groups in recent years. However, recent international consensus reports support early reconstruction for UGS anomalies associated with CAH. In our experience, the vast majority of parents desire early clitorolabioplasty for their child, due to the potential psychosocial ramifications of raising a girl with masculinized genitalia.

The optimal timing for vaginoplasty also remains a point of debate. A consensus statement on CAH from the Lawson-Wilkins Pediatric Endocrinologic Society and the European Society for Pediatric Endocrinology recommends surgery in the 2–6-month-old range for those with a high confluence, and surgery between 12 months and adolescence is not recommended.¹ We, along with others, believe that vaginoplasty, regardless of the vaginal confluence location, is best combined with simultaneous clitoroplasty and labioplasty.^{2–7} This allows the surgeon to utilize the redundant phallic skin to reconstruct labia minora and a mucosa-lined vestibule. Additionally, several authors have noted that maternal estrogen stimulation of the child's genitalia results in thicker vaginal tissue that is better vascularized, making vaginal mobilization easier to perform.^{2,8–13} We recognize that many girls who undergo early vaginoplasty will require a minor revision at puberty, and freely acknowledge this to the families of our patients. If vaginoplasty is deferred until puberty, a second operation is obviously required, and it is technically more difficult to perform. There is inadequate evidence at this time to give up our practice of early vaginoplasty, except in rare cases of a very small, high vagina.

When performing clitoroplasty today, every effort is made to not only provide good cosmesis, but also to retain normal clitoral innervation. Clitoridectomy has no role today. The neurovascular bundles which innervate the glans clitoris lie dorsally, along Buck's fascia, fanning out laterally more distally as in the male (Figure 73.2). These areas must be avoided at all times. Removal of spongy corporal tissues via ventral corporotomies allows the clitoris to be reduced in

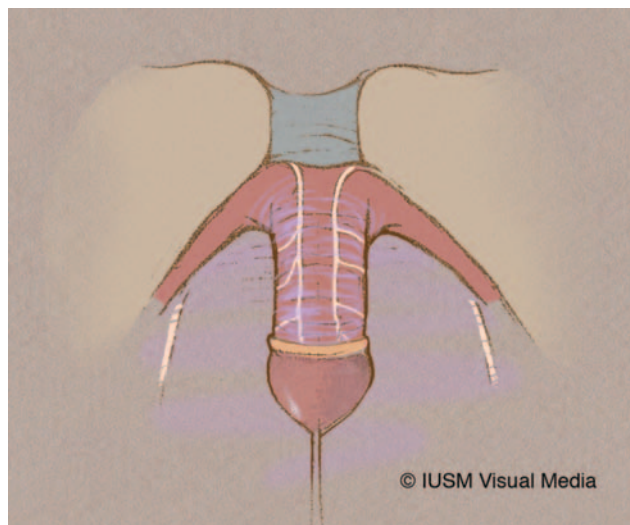


Figure 73.2 Hypertrophied clitoris with dorsal nerves and branches. IUSM Visual Media. All rights reserved. Reprinted with permission.

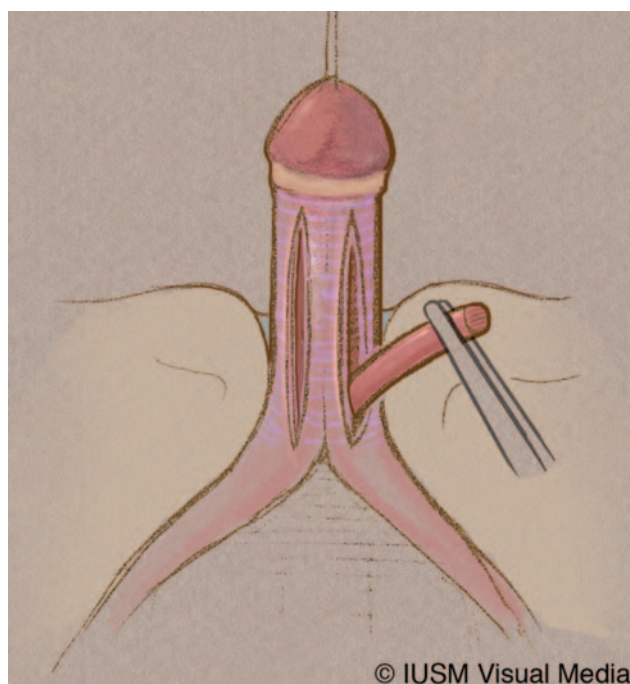


Figure 73.3 Hypertrophied clitoris with ventral corporotomies. Excision of spongy erectile tissue. IUSM Visual Media. All rights reserved. Reprinted with permission.

length, theoretically without injuring innervation (Figure 73.3).

Vaginoplasty

Current vaginal reconstructive techniques fall into one of four major types: cut-back vaginoplasty, flap

vaginoplasty, pull-through vaginoplasty, or complete vaginal replacement. The cut-back vaginoplasty is contraindicated in UGS anomalies and is only appropriate for simple labial fusion. The flap vaginoplasty is applicable to a low (distal) and to mid-level confluences, and may be used in combination with other techniques such as partial urogenital mobilization (PUM, discussed below), total urogenital mobilization (TUM, discussed below), or pull-through procedures. In flap vaginoplasty, the posterior walls of the sinus and vagina are opened, leaving the anterior wall intact. A perineal based skin flap is then advanced into the open vagina (Figure 73.4). It is critical to note that this procedure alone does not change the level of the confluence, but rather only opens the introitus and urogenital sinus. We and others believe that flap vaginoplasty alone should never be used for a high confluence, as it may result in a short hypospadiac urethra, vaginal voiding, infections, and even incontinence.^{4,13} For the very high confluence, a pull-through procedure is usually indicated. In this procedure, the vagina is separated from the UGS leaving an opening in the sinus which is closed, allowing the sinus to become the urethra. In most cases, a perineal skin flap will be required as well to allow the vagina to reach the perineum. Complete vaginal replacement can be achieved using several techniques, but is used only for a rudimentary or absent vagina.

When vaginoplasty is planned, patients should undergo either a full mechanical bowel prep or an enema preoperatively. Intravenous broad spectrum antibiotics should be given as well. Endoscopy should then be performed, as mentioned previously. A Fogarty catheter should be placed in the vagina with the balloon inflated (Figure 73.5). A Foley catheter should then be anchored in the bladder. Both are kept sterile, while the child undergoes a circumferential body prep from the nipples to the feet. The child is then passed through the aperture in the drapes. This allows the procedure to be performed in the supine frog-legged position, which maximizes exposure for the surgeon and assistants. Additionally, the child can be rotated prone during the case, if necessary, improving exposure to a high confluence (Figure 73.6).

Reconstruction for the low vaginal confluence with clitoral hypertrophy

The majority of children who undergo surgery for DSD or UGS anomalies have a low vaginal confluence amenable with a flap vaginoplasty. They usually have clitoral hypertrophy as well. Clitoroplasty and classic flap vaginoplasty are hence described.

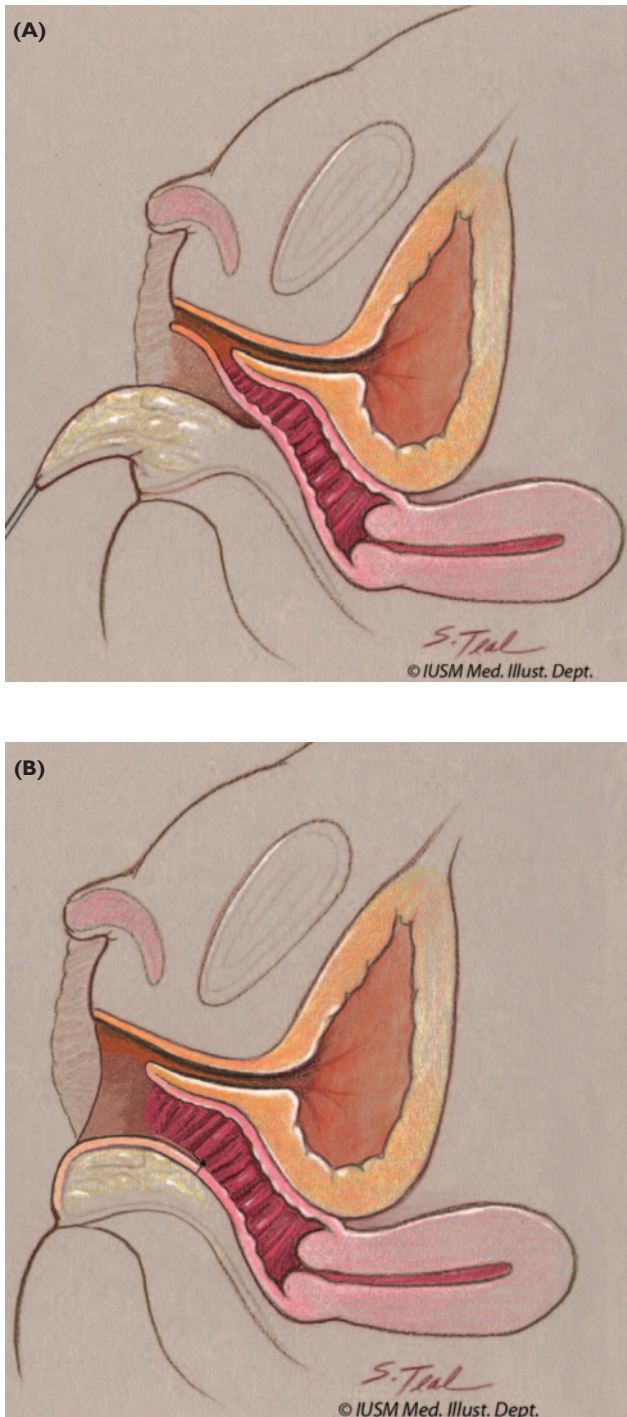


Figure 73.4 Flap vaginoplasty. (A) Perineal flap mobilized. (B) Flap sewn to opened sinus and vagina.

A traction suture is placed through the glans and the proposed incisions are outlined and infiltrated with 0.5% lidocaine with 1 : 200 000 epinephrine for hemostasis. Parallel longitudinal lines are drawn beside the ventral mucosal strip and around the meatus toward the glans and then around the coronal margin. A perineal-based omega flap is drawn, with the apex of the

flap at the ideal location of the vaginal orifice (Figure 73.7). A 'Y' shaped line is then drawn around the posterior aspect of each labia majora. The incision begins at the coronal margin, with ample skin left with the glans for a clitoral hood, as this skin has been shown to be second only to the glans itself in sensitivity.¹⁵ The clitoris is then degloved, as is done for hypospadias surgery, leaving the ventral mucosal strip intact. Dissection proximally is taken to the level of the bifurcation of the corporal bodies ventrally and the pubis dorsally. Care should be taken to avoid injury to the dorsal neurovascular bundles. A tourniquet is then placed at the base of the clitoris. Longitudinal incisions are then made in Buck's fascia on the ventral-most aspect of both corporal bodies, from the glans to the bifurcation of the corpora. The spongy erectile tissue is sharply dissected initially, and then teased from the underside of the tunics (Figure 73.3). The tunics are left undisturbed, except for the ventral corporotomies. No tunical tissue should be excised. The proximal ends of the erectile tissues are suture ligated, ensuring that the dorsal neurovascular bundles are not entrapped. Efforts to decrease the size of the glans are controversial and, if attempted, should only be performed ventrally near the midline, similar to the creation of glans wings for hypospadias repair. The glans itself is innervated by perforating branches located at the dorsal junction of the glans and corpora. Therefore, excision of glanular epithelium to conceal the glans is to be avoided. Additionally, no data suggest that a larger glans is detrimental to sexual function. At this point, the glans is secured to the corporal stumps. In our experience, if the glans is sewn to the pubis, an abnormally high clitoral position results.

Once clitoroplasty is complete, the flap vaginoplasty is begun. The omega flap is incised, exposing the urogenital sinus. The flap must be long enough to provide a tension-free anastomosis to the apex of the posterior vaginal incision and wide enough to provide a normal-caliber introitus. The posterior wall of the vagina is then dissected off the rectum. After placement of stay sutures in the meatus, the posterior wall of the sinus is then opened in the midline and extended proximally into the posterior wall of the vagina. It is critical to note that the distal third of the vagina is usually narrow, and therefore, the posterior wall incision must be carried proximally until normal-caliber vagina is encountered. The apex of the perineal skin flap is then anastomosed to the apex of the vaginal incision and an interrupted anastomosis is completed.

The phallic skin is unfurled and divided in the midline, stopping short of the base, to allow for a clitoral hood. Labia minora are created with the split preputial

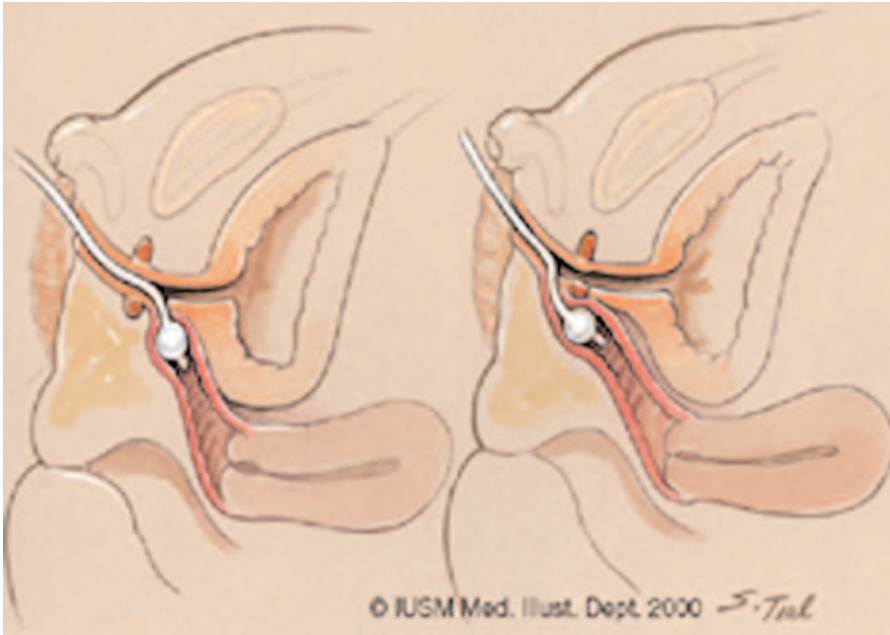


Figure 73.5 Fogarty catheter placed in the vagina in high confluence (left) and low confluence (right). IUSM Medical Illustration Department. All rights reserved. Reprinted with permission.

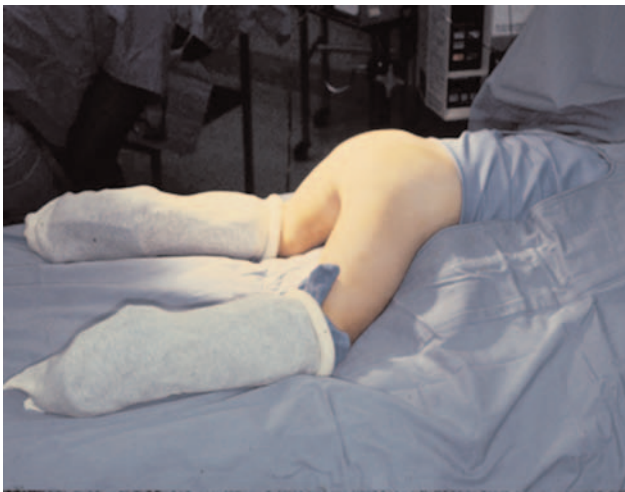


Figure 73.6 Total lower body preparation allows prone approach. From reference 14, with permission.

skin, which is moved inferiorly and anastomosed to the preserved ventral plate and the lateral vaginal wall. The 'Y' shaped skin lines on the posterior aspect of each labia majora are then incised. The labia are mobilized posteriorly and secured alongside the vagina as a Y-V plasty. The vaginal introitus should now reside between the labia minora and majora (Figure 73.8).

Reconstruction for the high vaginal confluence

Most authors believe that complete separation of the vagina from the UGS with a pull-through procedure, as

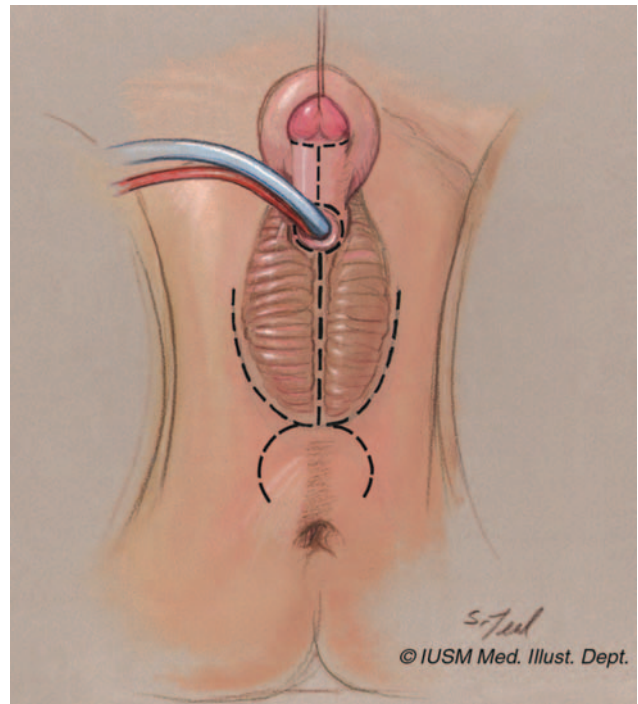


Figure 73.7 Proposed omega-shaped perineal skin flap. IUSM Medical Illustration Department. All rights reserved. Reprinted with permission.

described by Hendren and Crawford,¹⁶ is the best procedure for a high vaginal confluence. A high confluence can be seen in both CAH and pure UGS anomalies, although it is much less common than a low confluence. The most difficult and important component of a

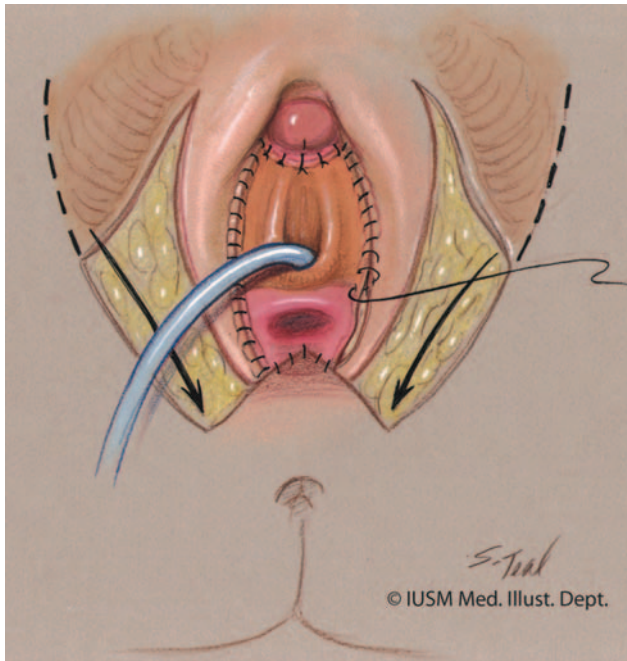


Figure 73.8 Labioplasty. Split phallic skin has been sewn in place as labia minora. Proposed Y-V plasty for labia majora. IUSM Medical Illustration Department. All rights reserved. Reprinted with permission.

pull-through vaginoplasty is separation of the vagina from the urethra. This area is also difficult to visualize, especially in the supine or lithotomy positions.

The procedure is begun in the same way as described previously for the low confluence, with endoscopy and clitoroplasty. (If a pure UGS is present, the procedure is begun prone after endoscopy.) We find it easier to then rotate the child to the prone position. The perineal omega-shaped flap incision is made, as previously described, and then the flap is retracted posteriorly, with dissection carried out in the midline between the posterior wall of the sinus/vagina and the rectum. As dissection continues proximally, the rectum is retracted posteriorly with a small Deaver to expose the entire UGS without the need to divide the rectum. The sinus is then divided in the midline posteriorly to the level of the normal caliber vagina. The Deaver is then placed in the vagina, and with upward traction, the anterior wall of the vagina and its confluence with the sinus is exposed (Figure 73.9). This allows dissection of the urethra from the vagina with good visualization. The tissues are very thin in this area, with no true tissue plane. The surgeon should err on the side of the vagina. The dissection becomes easier more proximally. The urethra can then be tubularized in two or three layers over a Foley catheter. The anterior wall of the vagina is

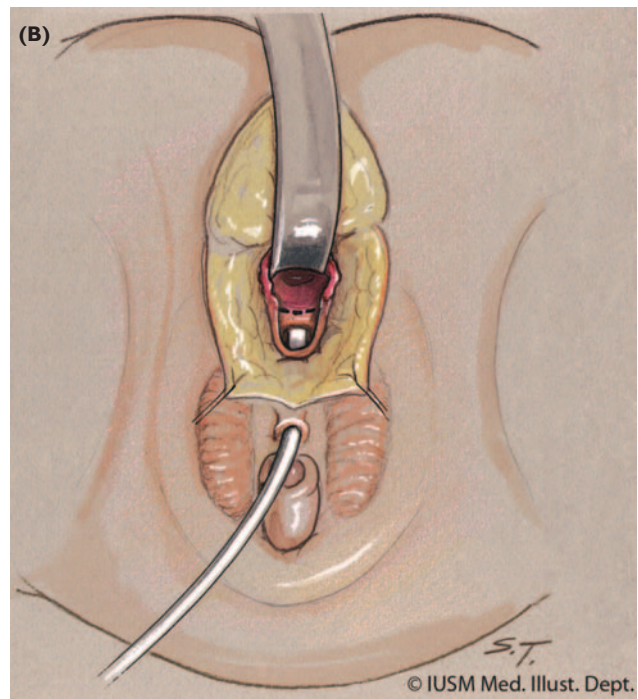
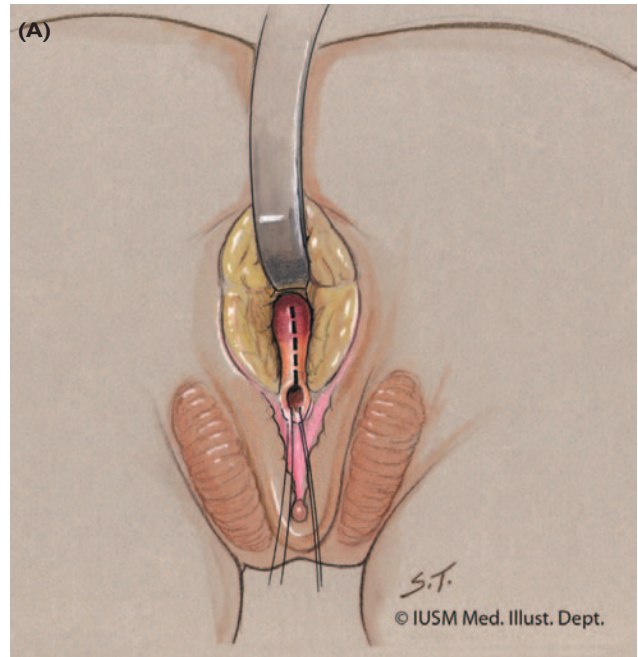


Figure 73.9 (A) An omega perineal flap has been developed and the sinus exposed. Proposed midline incision to open sinus and vagina. (B) Retractor in vagina. Proposed incision line drawn to separate the vagina from urethra. IUSM Medical Illustration Department. All rights reserved. Reprinted with permission.

mobilized caudally, toward the perineum (Figure 73.10). Skin flaps or preputial skin (if present) are then used to secure the vagina to the perineum.³ When preputial skin is not available, a buttock flap or a laterally based

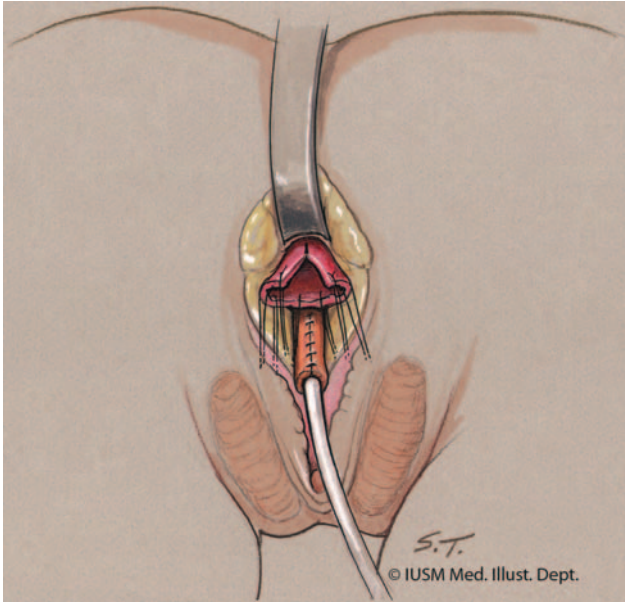


Figure 73.10 Pull-through vaginoplasty. Vagina mobilized and posterior vaginal wall spatulated. Sinus tubularized to create a urethra. IUSM Medical Illustration Department. All rights reserved. Reprinted with permission.

skin flap can be used. The child is then returned to the supine position, and the posterior perineal flap is anastomosed to the spatulated posterior vaginal wall as described previously for flap vaginoplasty (Figure 73.11). Labioplasty can now be performed as described above. In patients with a high confluence, especially if multiple flaps have been used, the legs are bound together loosely for several days postoperatively to minimize tension on the flaps.

Total and partial urogenital mobilization

Total urogenital mobilization was described in 1997 by Alberto Pena¹⁷ as a means to repair the UGS component of a cloaca. This procedure involves circumferential dissection of the UGS, mobilizing it towards the perineum. He noted a significant decrease in operative time, superior cosmesis, and decreased risks of fistula, vaginal stenosis, or acquired atresia with TUM. The original descriptions of the procedure included amputation of the mobilized sinus tissue so that the vagina and urethra could be sewn flush to the skin. In 1999, Rink and Adams¹³ reported use of this sinus tissue to create a mucosa-lined vestibule or a Passerini flap (anterior vaginal wall flap) when a pull-through procedure is

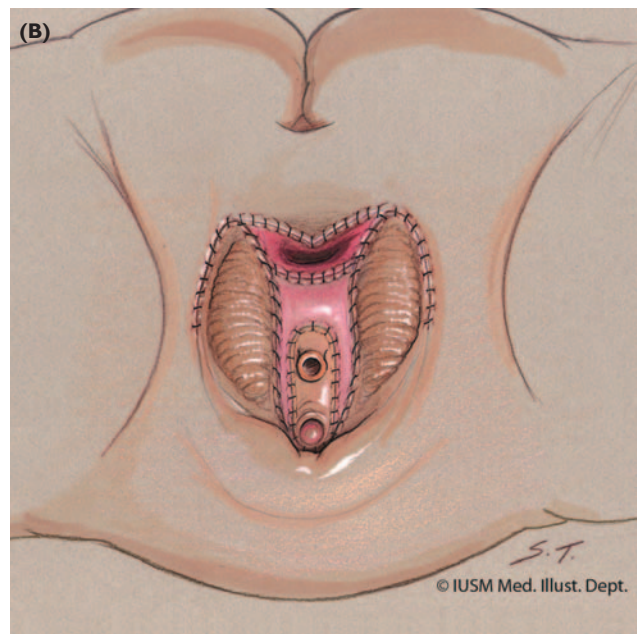
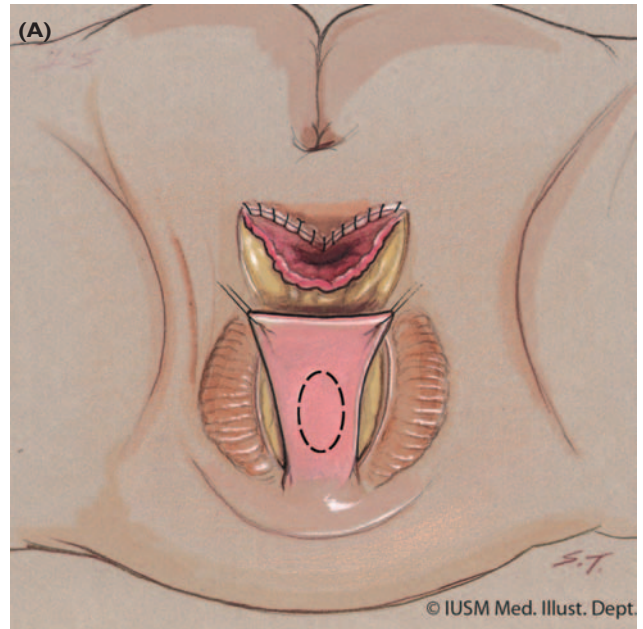


Figure 73.11 (A) Modified Gonzalez preputial flap to create an anterior vaginal wall; the posterior flap has been anastomosed to the spatulated vagina. (B) Creation of mucosa-lined vestibule and Y-V labioplasty. IUSM Medical Illustration Department. All rights reserved. Reprinted with permission.

performed. Other authors have reported successful results using this technique more recently, including use of this tissue to replace the posterior perineal-based skin flap (which is hair bearing skin).^{18,19} We have incorporated TUM into many of our UGS repairs in recent

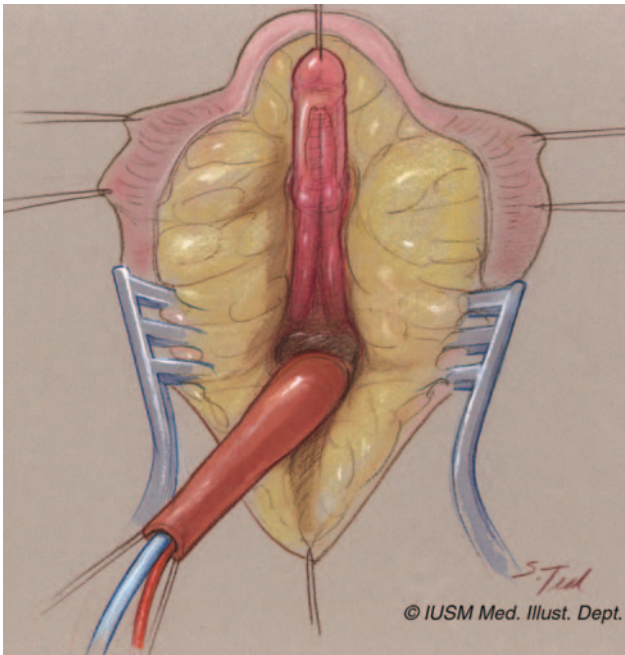


Figure 73.12 Total urogenital mobilization, with the sinus mobilized. IUSM Medical Illustration Department. All rights reserved. Reprinted with permission.

years. It allows an intermediate confluence to reach the perineum without requiring vaginal separation. The high confluences may still require a pull-through procedure, with separation of the vagina and urethra, but it is more easily performed after the sinus has been mobilized caudally. TUM is often considered to be its own type of vaginoplasty, allowing the vagina to be sewn flush to the perineum; however, a flap or pull-through vaginoplasty is often additionally required.

TUM is performed after endoscopy and clitoroplasty, as previously described. Once the posterior dissection between rectum and posterior vaginal wall has been extended to the peritoneal reflection, the anterior wall of the sinus is mobilized off the phallus (Figure 73.12). The circumferential dissection is carried out directly on the sinus tissue, continuing proximally under the pubis (Figure 73.13). As the avascular ligaments from the pubis are divided, the entire UGS is felt to 'give' and moves toward the perineum. Due to concerns regarding the potential risk for sphincteric or nerve injury to the bladder neck area, Rink et al²⁰ proposed partial urogenital mobilization (PUM). In PUM, the dissection ceases at the pubourethral ligament anteriorly (Figure 73.14). This still allows use of the mobilized sinus tissues to improve cosmesis and create a mucosa-lined vestibule, but avoids the aggressive infrapubic dissection. This procedure is applicable

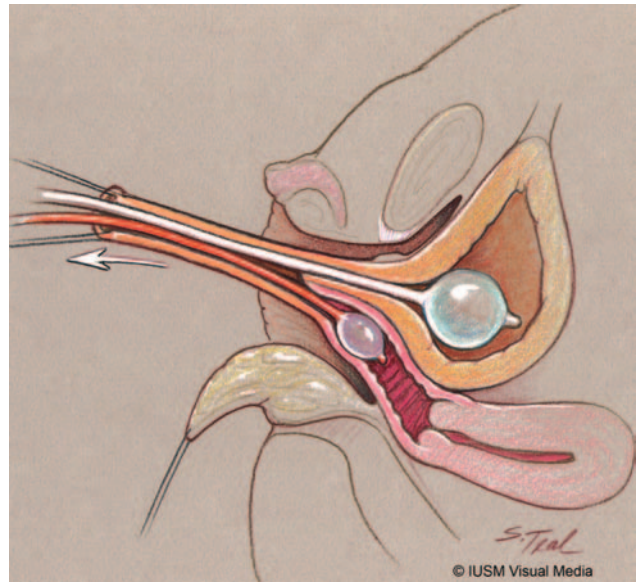


Figure 73.13 Total urogenital mobilization. The sinus is mobilized circumferentially, including beneath the pubis. IUSM Medical Illustration Department. All rights reserved. Reprinted with permission.

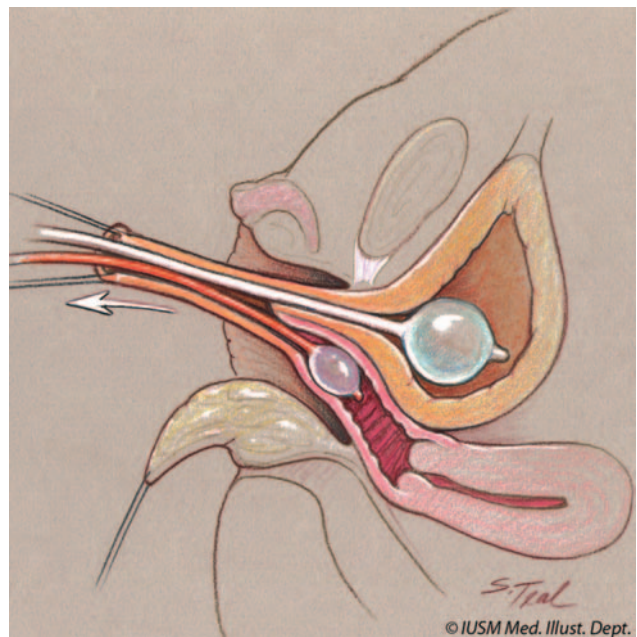


Figure 73.14 Partial urogenital mobilization. Dissection stops at the pubourethral ligament. IUSM Medical Illustration Department. All rights reserved. Reprinted with permission.

to the majority of patients in our experience. If more mobilization is necessary for a very high confluence, then TUM is easily carried out, by extending the anterior dissection under the pubis as described.

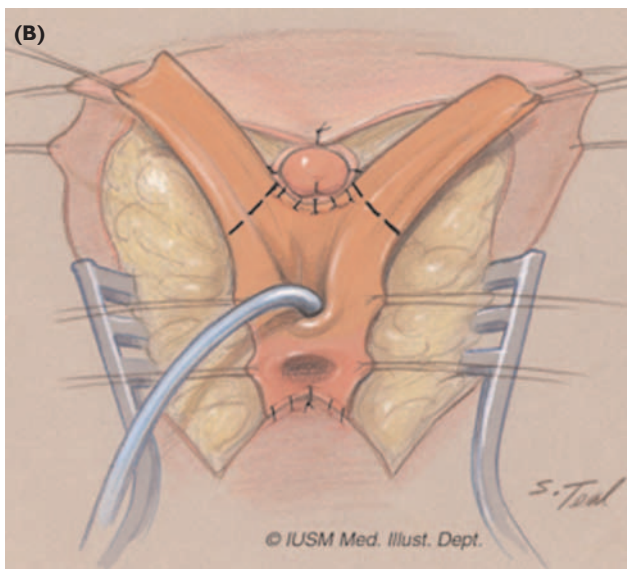
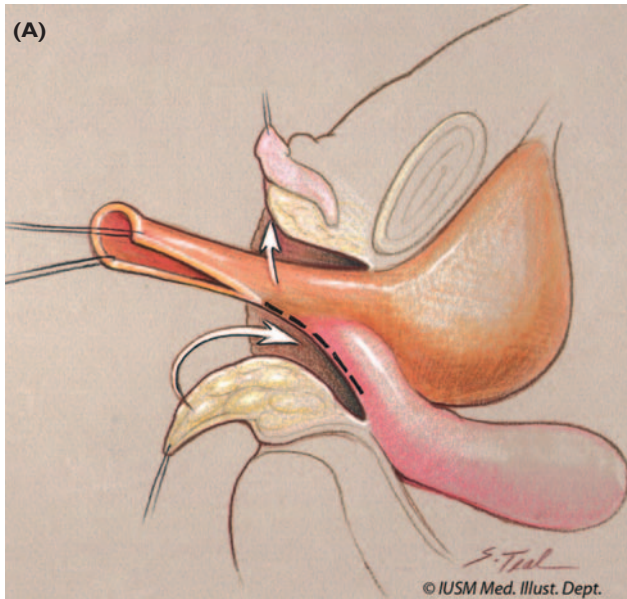


Figure 73.15 A ventral incision in the mobilized sinus. (B) Sinus opened allows the creation of a mucosa-lined vestibule. IUSM Medical Illustration Department. All rights reserved. Reprinted with permission.

Once urogenital mobilization has adequately been performed, the Fogarty balloon is easily palpable in the vagina. The posterior wall of the vagina is opened between stay sutures in the midline. If the vagina is near the perineum at this point, anastomosis to the skin may be performed. If not, the posterior omega-shaped skin flap may be sewn into the spatulated vagina posteriorly to augment the vaginal introitus. We prefer the latter. The excess mobilized sinus tissue can then be split

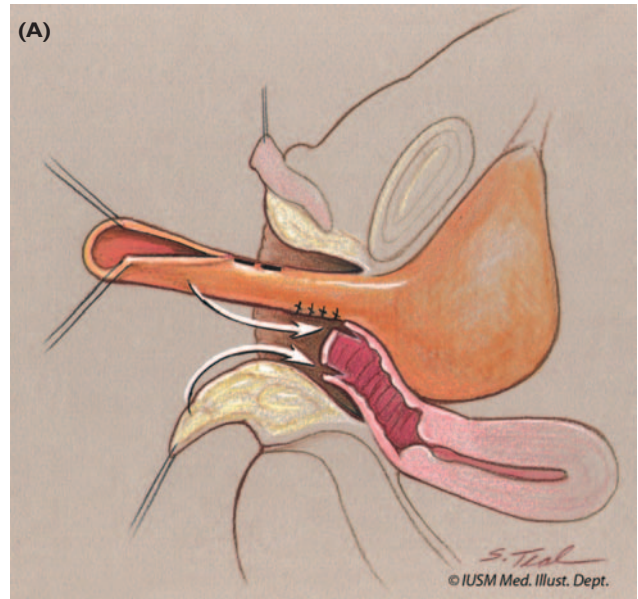


Figure 73.16 Total urogenital mobilization. (A) The sinus can be split dorsally to create an anterior vaginal wall for pull-through vaginoplasty. IUSM Medical Illustration Department. All rights reserved. Reprinted with permission. (B) The opened sinus now becomes the anterior vaginal wall.

ventrally and used to provide a mucosa-lined vestibule (Figure 73.15). If the vagina is still high, the anterior wall of the vagina should be separated from the urethra and bladder neck and a pull-through procedure performed. Again, we think this dissection is best performed in the prone position. The mobilized sinus in this situation is split dorsally, allowing it to become the anterior vaginal wall as a Passerini flap (Figure 73.16). Labioplasty is then performed as described previously.

Reconstruction for cloacal malformations

The initial management of the child with a cloacal anomaly involves prompt stabilization because the child is often quite ill due to abdominal distention that can lead to respiratory compromise. Historically, a pull-through procedure was performed initially, followed by genitourinary reconstruction at a later date, at times after puberty. It is now strongly recommended that all abnormalities be corrected in a single stage, as this allows optimal exposure for the difficult vaginal and rectal separation, without further distortion of the tissues from prior rectal pull-through procedures. Levitt and Pena²¹ recently stated that there are three pitfalls in the management of newborns with a cloaca: failure to recognize and manage hydrocolpos, colostomy or vesicostomy problems, and clinical misdiagnosis. Today, surgical management involves four steps: decompression of the gastrointestinal tract, decompression of the urinary tract, correction of nephron destructive or potentially lethal urinary anomalies, and definitive repair of the cloaca.

Decompression of the gastrointestinal tract

Decompression of the gastrointestinal tract is done by colostomy. While all surgeons agree on the need for colostomy, the location is a point of debate. In 1992, Hendren²² recommended a divided transverse colon colostomy, because of difficulty obtaining a bowel segment for vaginoplasty during the rectal pull-through procedure when a low colostomy was performed. A divided transverse colostomy maintains the left colic blood supply. However, the longer distal limb can lead to problems with acidosis from urine absorption in some cases. Levitt and Pena²¹ more recently advocated a divided colostomy in the descending colon just distal to the retroperitoneal portion, as this maintains the availability of enough distal colon for a pull-through, with less risk of prolapse. We have favored a proximal colostomy, but have at times seen clinically problematic acidosis.

At the time of neonatal colostomy, endoscopy can be performed to define anatomy, decompress the vagina (or vaginas) and bladder and irrigate the rectal fistula. The cystoscope tends to pass directly into the vagina in most cases, and entry into the urethra and bladder can be challenging, due to the anterior displacement of the urethra and bladder neck by the distended vagina. The rectal fistula may also be difficult to locate, as it is often located in the septum between

duplicated vaginas. A combination of retrograde and antegrade irrigation (through the distal limb of the colostomy) is usually successful in clearing inspissated mucus and meconium. We find it helpful to leave small catheters in all channels, to allow genitography to further delineate the anatomy.

Decompression of the genitourinary tract

Despite neonatal decompression of the vagina, bladder, and distal colon, at times voiding into the vagina, rectum, or both continues, leading to poor urinary drainage, abdominal distention, urinary infection, and/or acidosis. This can usually be managed by intermittent catheterization of the common channel, even though the catheter usually enters the vagina preferentially. In some cases with a long common channel, catheterization can be difficult, requiring a cut-back procedure, as described by Hendren.²² If these approaches fail, vesicostomy or vaginostomy may be required. Levitt and Pena²¹ have found vaginostomy helpful but we think that intermittent catheterization or vesicostomy, or both, will usually keep the vagina decompressed. Only when these measures have failed, should vaginostomy be performed, as it tethers the vagina to the abdominal wall and makes subsequent pull-through or TUM more difficult.

Repair of obstructive urinary pathology

Renal structural abnormalities are common in patients with a cloacal anomaly, some of which are clinically significant obstructions. Obstructive lesions should be treated promptly. Vesicoureteral reflux, which is quite common, can usually be managed medically, as long as urinary infection is minimized.

Definitive repair of cloacal anomalies

Ideally, definitive repair of the child with a persistent cloaca is performed between 6 and 12 months of age, provided the overall health and nutrition of the child is adequate. Full mechanical bowel prep, as well as irrigation of the distal limb of the colostomy should be performed preoperatively. Endoscopy should be repeated at time of repair, to re-establish the anatomy firmly prior to proceeding. We have found it helpful to place a Foley catheter in the bladder, and different colored or labeled Fogarty catheters in the vagina

(or vaginas) and rectal fistula. The catheters should be kept sterile while circumferential whole body prep is performed, as described for UGS repairs. This prep and draping allows the child to be rotated supine to prone and vice versa during the case as needed.

Definitive posterior sagittal anorectovaginourethroplasty (PSARVUP) is begun with the child in the prone jack-knife position, with the pelvis elevated on rolls. An electrical stimulator is used to determine the point of maximal contraction, which is marked for later anorectal placement. The proposed locations of the perineal body and urethra are also marked. The entire dissection is begun in the midline until mobilization of the rectum and vagina is commenced. The initial incision extends from the coccyx to the posterior aspect of the common channel orifice. Sutures are used to mark the sphincteric muscles as they are encountered. In the past, we found it useful to open the sinus posteriorly, to expose the confluences. With TUM, this is not ideal, as it may limit the options for use of the sinus tissue for reconstruction. When the rectal fistula is identified, it is opened posteriorly and stay sutures are placed. The sutures can be used for traction to help mobilize the rectum away from the vagina (or vaginas). The rectum, vagina, and urethra all share common walls, and so dissection should always err on the side of the vagina, as it is better to enter the vagina than the urethra or rectum. The rectum should be circumferentially mobilized proximally, well above the sacrum. Rarely, with a very high rectal confluence, the child may need to be rotated supine for abdominal exploration to free the rectum proximally.

Prior to TUM, the vagina is separated from the sinus, which is an even more tedious dissection than separation of the rectum from the sinus. With TUM, the vagina may not require separation. In the classic vaginal separation technique, the posterior aspect of the vagina is opened at the level of the confluence. Stay sutures are placed. A malleable retractor is placed into the opened posterior vaginal wall to expose the anterior wall. Sharp dissection (rather than cautery) should proceed cautiously to mobilize the urethra. Frequently the vagina almost encircles the urethra, making dissection even more difficult. Failure to recognize this anatomy can result in injury. The outer wall of the vagina is white, which is paramount to identifying the anatomy clearly. Great care must be taken to avoid devascularizing the vagina during mobilization. At this point, the vagina has usually been mobilized adequately to reach the perineum. If not, skin flaps can be used to reach the spatulated vagina. With an extremely high vagina or vaginal agenesis, a bowel vagina interposition may be

necessary to reach the perineum, which obviously requires abdominal surgery.

Before the vagina is brought to the perineum, the openings in the common channel should be closed in two or three layers, to become a urethra. If the channel is large and vagina like, it should be opened in its entirety and tailored over a Foley catheter. The vagina is then secured to the perineum. Rotation of the vagina to prevent overlapping suture lines is recommended if there is any concern over vaginal injury. The Foley catheter is left indwelling for 2 weeks. The perineal body is then constructed, and the rectum pulled through to the perineum. Rectal tailoring may be required. The rectum is placed in the center of the sphincteric muscle complex, ensuring that muscle meets posterior to the rectum. Rectal dilatation is begun 2 or 3 weeks postoperatively and the colostomy closed in 3 months if all has healed well.

Once the Foley catheter has been removed, the urinary tract must be monitored closely, as poor emptying due to a neuropathic component is seen in up to one-third of patients. Clean intermittent catheterization should be instituted early if any concerns regarding poor emptying arise.

The TUM technique described by Pena is now widely accepted for cloacal repairs. It is technically easier to perform and leads to shorter operative times and decreased blood loss. As described for UGS repairs, TUM involves a 360° mobilization of the entire UGS. The technique is not different from that described for UGS repairs, once the rectum has been separated from the sinus. We have found the TUM technique to be extremely helpful, as it makes the most difficult part of the cloacal repair, vaginal separation from the urethra, unnecessary or much easier to perform. If the confluence is only 2 or 3 cm from the perineum, separation may not be needed. Continence concerns have been raised, but to date results have been similar to standard repairs. In fact, a recent review of our series of PUM and TUM procedures revealed that of 19 neuroanatomically normal children at least 3 years of age who underwent either TUM or PUM (for UGS or cloacal anomalies), all were continent and voiding, with the exception of one who was lost to follow-up.

SUMMARY

Management of UGS and cloacal anomalies is quite complex from both a surgical and psychosocial standpoint. A multidisciplinary approach is mandatory for children

with any degree of a DSD. Family support, education, and counseling are critical to a good functional outcome. Surgical reconstruction requires precise knowledge of each child's unique anatomy, delicate and precise tissue handling, and lifelong commitment by the surgeon. These anomalies occur in a spectrum of complexity, and the more difficult cases should be handled only in centers with expertise and experience in these areas.

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74 Laparoscopic surgery for stress urinary incontinence and pelvic organ prolapse

Chi Chiung Grace Chen and Marie Fidela R Paraiso

INTRODUCTION

Stress urinary incontinence (SUI) and pelvic organ prolapse (POP) are common phenomena in women. It is projected that 11.1% of the female population will undergo surgery for the above conditions in their lifetime with 30% of these women requiring reoperations for recurrence.¹ Annually, it is estimated that more than 135 000 and 300 000 inpatient surgeries are being performed to correct SUI and POP, respectively, at a combined cost of more than 1 billion US dollars.^{2,3} The growth in demand for services to care for these disorders will increase at twice the rate of the growth of the population over the next 30 years. Since the introduction of laparoscopic retropubic urethropexy in 1991, laparoscopic approach and techniques have been applied to most abdominal and vaginal procedures for SUI and POP. Recent advances have also included using robotic assistance to perform these laparoscopic procedures. Deciding whether to proceed with laparoscopic surgery is dependent upon the surgeon's experiences and skills as well as the available facilities and patient preferences. Other considerations include previous history of incontinence and prolapse procedures; patient characteristics such as age, weight, and ability to tolerate general anesthesia; presence of a foreshortened vagina and severe abdominopelvic adhesions; or the need for concomitant transvaginal repairs. Advantages of laparoscopic surgery include improved visualization of retropubic and pelvic anatomy due to magnification from the laparoscope; improved hemostasis; decreased postoperative pain and shortened hospitalization resulting in potential cost reduction; decreased recovery period with quicker return to work; and improved cosmesis from smaller incisions. Disadvantages of laparoscopy include an initial steep learning curve and technical difficulty with laparoscopic dissection and suturing; initial increased operating time; greater hospital costs secondary to increased operating room time and disposable laparoscopic instruments; the need for adequate facilities with knowledgeable ancillary staff; and lack of three-dimensional perspective. These disadvantages, along with limited

training in advanced laparoscopic techniques and the advent of minimally invasive midurethral slings and surgical kits for vaginal prolapse, have thwarted the widespread adoption of laparoscopic surgery for SUI and POP. Therefore, most of the literature, especially concerning prolapse procedures, consists of small series by expert surgeons. As such, the findings are susceptible to various biases and should be interpreted with caution as the efficacy of specific procedures can often be falsely amplified. In this chapter, we examine the procedures for SUI and POP separately by first discussing the anatomy and steps involved in the specific surgeries followed by summaries of the evidence on the efficacy of these different laparoscopic techniques.

GENERAL INTRAOPERATIVE CONSIDERATIONS

General surgical guidelines are followed intraoperatively including the placement of an orogastric or nasogastric tube for gastric decompression, prophylactic intravenous antibiotics, and pneumatic compression stockings. Patients are placed under general anesthesia in the low dorsal lithotomy position. A 16Fr 3-way Foley catheter (20–30 ml balloon) attached to continuous drainage with a port attached to sterile water or saline for retrograde bladder filling is placed.

We start with an infraumbilical trocar (Figure 74.1). The umbilicus is approximately at the L3–L4 level and the aortic bifurcation is at L4–L5. However, in obese women, the umbilicus is usually caudal to the bifurcation. Therefore, the infraumbilical trocar should be introduced at a more acute angle toward the pelvis in thin women and closer to 90° in obese women. We generally place two accessory ports in bilateral lower quadrants lateral to the rectus muscle and approximately 2 cm medial and cephalad to the anterior superior iliac spines to avoid ilioinguinal and iliohypogastric nerve damage.⁵ Care must also be taken to avoid the superficial epigastric artery, a branch of the femoral artery, which courses medial and cephalad, and can be visualized by transilluminating the anterior abdominal

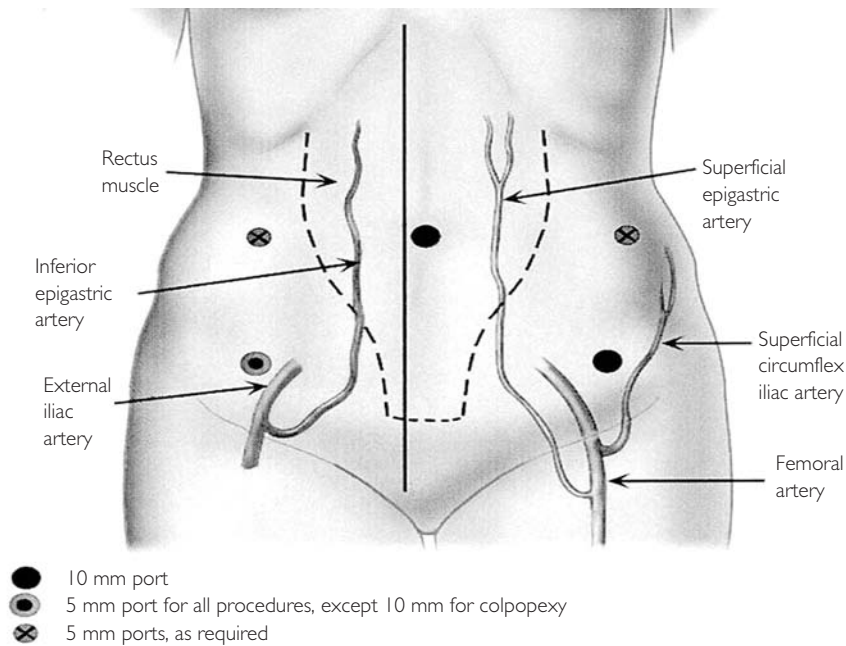


Figure 74.1 Anatomic landmarks of the anterior abdominal wall with suggested laparoscopic trocar positions. From reference 4 with permission.

wall. Additionally, the inferior epigastric artery, a branch of the external iliac artery, which runs lateral to and below the rectus sheath at the level of the arcuate line accompanied by two inferior epigastric veins, must also be averted. Although these vessels can often be visualized on the anterior abdominal wall laparoscopically, if not seen, injury can be avoided by placing trocars just lateral to where the round ligament exits the pelvis at the deep inguinal ring. An additional port, which may be necessary for prolapse procedures, may be placed on the principal surgeon's side at the level of the umbilicus along the midclavicular line thereby avoiding the superficial epigastric vessels.

After laparoscopic placement of the sutures, most knots are tied extracorporeally and not intracorporeally. Extracorporeal knot-tying is preferred due to the ability to hold more tension on the suture as well as the relative ease of execution. At the completion of the laparoscopic procedures, transurethral cystoscopy is performed to confirm the lack of sutures or injury to the bladder as well as ureteral patency.

LAPAROSCOPIC RETROPUBIC PROCEDURES FOR STRESS URINARY INCONTINENCE

The first published series of laparoscopic retropubic correction of urinary incontinence was the Marshall-Marchetti-Krantz (MMK) procedure, followed by another series describing laparoscopic MMK and

Burch colposuspension techniques.^{6,7} Since that time, there have been numerous modifications including varying the number and types of sutures, incorporation of synthetic mesh, staples, bone anchors, coils, tacks, fibrin sealant, and radiofrequency. A variety of suturing and needle devices have also been used to simplify laparoscopic suturing and knot-tying.

Anatomy

Anatomic landmarks within the space of Retzius include the most cephalad margin of the bladder, which is approximately 3 cm above the pubic symphysis; Cooper's ligament (iliopectineal line); the accessory or aberrant obturator veins; the obturator neurovascular bundles, which lie 3–4 cm above the arcus tendineus fascia pelvis (ATFP); the bladder neck, which is delineated during surgery by placing traction on the Foley bulb; and ATFP and arcus tendineus levator ani (ATLA), which insert into the pubic bone (Figure 74.2).

Techniques

The first step of the procedure consists of transperitoneal dissection into the space of Retzius. The lateral boundaries of this dissection include the medial umbilical folds, which are formed by the peritoneum overlying the obliterated umbilical arteries. As the

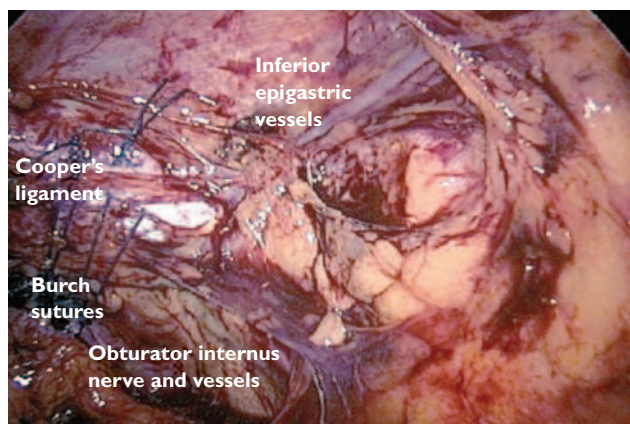


Figure 74.2 Laparoscopic view of the right space of Retzius with delineations of major anatomic structures and right periurethral Burch colposuspension sutures.

upper margin of the dome of the bladder is noted approximately 3 cm above the pubic symphysis when the bladder is filled with 300 ml of fluid, incision into the space of Retzius must be made a few centimeters above this to avoid bladder injury. Therefore, after filling the bladder with 300 ml of sterile water or saline (indigo carmine or methylene blue can also be added), a transverse incision 3 cm cephalad of the bladder reflection, between the medial umbilical folds, is made. Identification of the loose areolar tissue confirms a proper plane of dissection. Blunt and sharp dissection is carried out inferolaterally aiming towards the posterior-superior aspect of the pubic symphysis to decrease the risk of bladder injury until the aforementioned anatomic landmarks are delineated. Blunt dissection is carried out dorsally until vaginal palpation of the ischial spine is appreciated laparoscopically. Medial dissection over the urethra should be avoided to minimize blood loss and damage to the periurethral musculature and nerve supply.

In contrast to the intraperitoneal approach described above, some surgeons have advocated the extraperitoneal approach to enter the 'space of Retzius' if a retropubic urethropexy is to be performed in isolation without the need for concomitant intraperitoneal prolapse procedures or other reasons for entering the peritoneal cavity. The extraperitoneal approach essentially entails using a balloon dissector (Origin Medsystems, Menlo Park, CA; US Surgical Corp, Norwalk, CT) to delineate the space of Retzius without the need to enter the peritoneal cavity. The potential advantages are easier retropubic dissection leading to decreased operating time and fewer bladder injuries. However, a

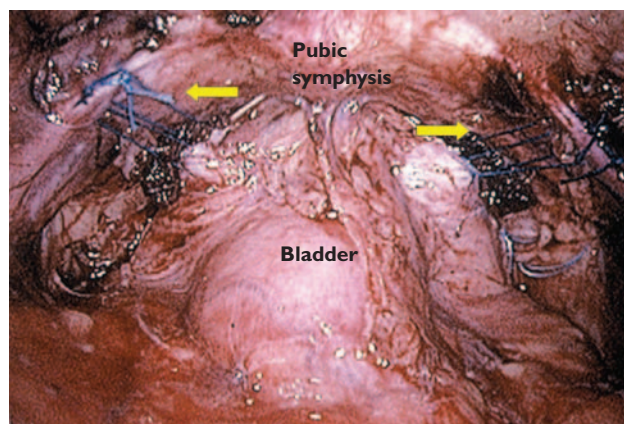


Figure 74.3 Laparoscopic view of the space of Retzius with two Burch colposuspension sutures on each side of the urethra. Notice that the sutures are tied under minimal tension resulting in suture bridges between Cooper's ligament and the periurethral vaginal wall (arrows).

contraindication to the extraperitoneal route is a history of previous retropubic surgery. Furthermore, history of previous low transverse or midline incisions also makes this approach difficult and prone to failure. In the English literature, there is one small study comparing the extraperitoneal with the intraperitoneal approach for laparoscopic Burch colposuspension and it found no difference in the subjective efficacy of either technique.⁸ Furthermore, there is one trial from Germany which found outcomes from either approach comparable with those of open Burch colposuspension.⁹ In general, we prefer the intraperitoneal approach as it allows for a large operating space thereby facilitating the safe and comfortable handling of sutures as well as for performing concomitant prolapse procedures such as culdoplasty. For the remainder of this chapter, we limit most of our discussions to laparoscopic retropubic urethropexies performed via the intraperitoneal approach.

Specifically, for MMK procedures, delayed absorbable sutures are placed through the vagina (excluding the vaginal epithelium) in a figure-of-eight fashion at the urethrovesical junction bilaterally. The sutures are then placed through the periosteum of the pubic bone and tied extracorporeally. One suture is placed on each side of the bladder neck (urethrovesical junction).

For Burch colposuspension, non-absorbable sutures are placed through the vagina (excluding the vaginal epithelium) in a figure-of-eight fashion at the level of the midurethral and bladder neck resulting in two sutures on each side of the urethra (Figure 74.3). Both arms of each suture are taken through ipsilateral Cooper's ligaments. The sutures are tied down extracorporeally with the vaginal wall elevated to the level

Table 74.1 Case series of laparoscopic Burch colposuspension with suturing technique

	No. of patients	Follow-up (months)	Cure (%)	Major complication rate (%)
Albala et al, 1992 ⁷	10	7	100	0
Liu, 1994 ¹²	132	18	96	7
Gunn et al, 1994 ¹³	15	4–9	100	0
Nezhat et al, 1994 ¹⁴	62	8–30	100	10
Langebrenke et al, 1995 ¹⁵	8	3	88	25
Carter, 1995 ¹⁶	50	12–36	100	6
Radomski and Hersehorn, 1996 ¹⁷	34	17	85	12
Flax, 1996 ¹⁸	47	2–15	73	13
Cooper et al, 1996 ¹⁹	113	8	87	24
Papasakelariou and Papasakelariou, 1997 ²⁰	32	24	91	6
Lobel and Davis, 1997 ²¹	35	34	69	23
Ross, 1998 ²²	48	24	89	6
Lee et al, 2001 ²³	160	36	91	17

of the ATFP. The resultant stabilized vaginal wall acts as a hammock between both arcus supporting the bladder neck. Care must be taken to avoid over tensioning the sutures leading to potential voiding dysfunction. Therefore, the vaginal wall should not be raised to the level of Cooper's ligament and there should be a suture bridge measuring approximately 1.5–2.0 cm.

There are several reported modifications of the above technique. In one randomized controlled trial, placement of only one suture on each side of the urethra was compared with the traditional two suture placement described above. Although the mean operative time was significantly decreased in the one suture group, objective and subjective rates of cure were significantly higher in the two suture group after 1 year (objective 83% versus 58%, subjective 89% versus 65%, respectively).¹⁰ Another randomized controlled trial addressed suturing Prolene™ mesh (Ethicon, Inc., Somerville, NJ) to the periurethral tissue then stapling it to Cooper's ligament compared with the traditional two suture placement and found significantly higher objective failure rates after 1 year in the mesh group (27% versus 11%) with no differences in subjective parameters.¹¹ As the traditional technique of two non-absorbable suture placements affords comparable if not superior outcomes to various modifications, we limit our discussions of clinical efficacy to this method unless otherwise specified.

Clinical results

Numerous case series have been published on the efficacy of laparoscopic Burch colposuspension with cure rates ranging from 69 to 100% and follow-up periods

ranging from 3 to 36 months (Table 74.1).^{7,12–23} Complication rates range from 0 to 25% with cystotomy being the most common intraoperative injury.

Laparoscopic Burch colposuspension versus open Burch colposuspension

There are ten randomized controlled trials comparing laparoscopic with open Burch colposuspension using varying techniques (Table 74.2). Objective cure rates for laparoscopic Burch colposuspension compared with open procedures range from 57 to 94% and from 64 to 96%, respectively, while subjective cure rates range from 55 to 100% and from 55 to 96%, respectively, with follow-up periods ranging from 6 months to 5 years.^{24–33} The authors from a recent Cochrane review concluded that there were no statistical differences in the cure rates between the two techniques, if performed with the conventional two sutures on either side of the urethra.³⁴ The only exception was the trial by Burton who demonstrated decreased cure rates after laparoscopy with 10% of patients requiring repeat incontinence procedures compared with 0% in the open group.²⁵ However, the results may have been confounded by the primary surgeon's lack of experience in performing laparoscopic Burch procedures. When comparison of the conventional open technique was made with modifications of the technique laparoscopically, such as using mesh and staples instead of suture or using only one suture (on each side of the urethra), the open procedures resulted in statistically higher cure rates (92–96% versus 74–80%).^{26,31} Overall, patients who underwent laparoscopic Burch colposuspensions sustained fewer perioperative complications (relative

Table 74.2 Randomized controlled trials comparing traditional open and laparoscopic Burch colposuspension

	Type of Burch colposuspension	No. of patients	Follow-up (months)	Objective cure (%)	p Value
Ross, 1995 ²⁴	Open	30	12	93	NS
	Laparoscopic	32		94	
Burton, 1997 ²⁵	Open	30	5 years	90	
	Laparoscopic	30		57	
Su et al, 1997 ²⁶	Open (3 sutures)	46	12	96	0.044
	Laparoscopic (1 suture)	46		80	
Miannay, 1998 ²⁷	Open	36	24	64	NS
	Laparoscopic	36		68	
Saidi et al, 1998 ²⁸	Open	70	16	92	NS
	Laparoscopic (extraperitoneal approach)	87		91	
Summitt et al, 2000 ²⁹	Open	28	12	88	NS
	Laparoscopic	34		93	
Fatthy et al, 2001 ³⁰	Open	34	18	88	NS
	Laparoscopic	40		85	
Ankardal et al, 2004 ^{31*}	Open (2 sutures)	120	12	92	<0.001
	Laparoscopic (mesh and staples)	120		74	
Carey et al, 2006 ³²	Open (2–3 sutures)	104	6, 24, 3–5 years	78 (6 months)	NS
	Laparoscopic (2–3 sutures)	96		72 (6 months) [†]	
Kitchener et al, 2006 ³³	Open	147	24	70	NS
	Laparoscopic	144		80	

*Polypropylene mesh and staples were used for the laparoscopic Burch while sutures were used for the open Burch.

[†]At 3–5 years follow-up (mean 3.7 years), there were no statistical differences in patient reports of recurrent stress and urge incontinence symptoms. NS, not significant.

risk [RR] 0.72, 95% confidence interval [CI] 0.54–0.97); however, the risk of cystotomy was higher in the laparoscopic group (RR 2.37, 95% CI 1.03–5.48).³⁴ Additionally, laparoscopy resulted in longer operative times, decreased postoperative pain, hospital stays, and recovery period. In terms of postoperative complication rates, there were no statistical differences in rates of de novo detrusor overactivity or voiding dysfunction.

There is one study that addressed the cost-effectiveness of laparoscopic versus open Burch colposuspension in the UK and it found higher healthcare resource costs associated with laparoscopy over a 6-month period.³⁵ However, after 24 months, the laparoscopic arm had higher quality-adjusted life years and therefore may be cost effective.

Laparoscopic Burch colposuspension versus self-fixing mid-urethral slings

Minimally invasive self-fixing mid-urethral sling procedures such as the tension-free vaginal tape (TVTTM) (Ethicon Women's Health and Urology) and SparcTM (American Medical Systems, Minnetonka, MN) combine the theoretic advantages of laparoscopy such as shorter patient recovery periods without the need for training in advanced laparoscopic techniques. There are eight randomized controlled trials in the literature

that compare the traditional two suture (on each side of the urethra) laparoscopic Burch colposuspension with either TVT or Sparc mid-urethral sling procedures^{36–43} and one randomized controlled trial that used the tacker mesh technique (Origin Tacker System, General Surgical Innovations) for the laparoscopic colposuspension compared with TVT⁴⁴ (Table 74.3). However, we did not include two randomized controlled trials (Adile et al³⁸ and Mirosh et al⁴²) in our discussion as they are both published only in abstract form and neither of them described their randomization process nor the exact timing of their follow-up periods. A recent Cochrane review concluded that overall the objective cure rate was higher in the mid-urethral sling group compared with laparoscopy within a follow-up period of 18 months (RR 0.88, 95% CI 0.81–0.95) but there were no clear statistical differences in subjective cure rates (RR 0.91, 95% CI 0.80–1.02).³⁴ Furthermore, there were no differences in urodynamic cure rates.^{39–41} However, one trial did find a higher reoperation rate in the TVT group after 1 year (8% versus 3%).³⁷ Most trials reported improvements in quality of life assessments after either surgical technique without statistical differences between the two interventions.^{40,41,43} Overall, there were no statistical differences in rates of voiding dysfunction (RR 1.06, 95% CI 0.47–2.41) or de novo detrusor

Table 74.3 Randomized controlled trials comparing self-fixing mid-urethral sling and traditional laparoscopic Burch colposuspension

	Type of procedure	No. of patients	Follow-up (months)	Objective cure (%)	p Value
Liang and Soong, 2002 ³⁶	TVT	23	18	83	NS
	Laparoscopy (1 suture)	22	23	77	
Persson et al, 2002 ³⁷	TVT	38	12	89	NS
	Laparoscopy	32		87	
Ustun et al, 2003 ³⁹	TVT	23	11	83	NS
	Laparoscopy	23	14	83	
Maher et al, 2004 ⁴⁰	TVT	40		85	
	Laparoscopy	40		78	
Paraíso et al, 2004 ⁴¹	TVT	33	21	97	0.056
	Laparoscopy	33		81	
Valpas et al, 2004 ⁴⁴	TVT	70	12	86	0.001
	Laparoscopy (tacker mesh system)	51		57	
Foote et al, 2006 ⁴³	Sparc	49	24	77	NS
	Laparoscopy	48		82	

NS, not significant.

overactivity (RR 0.8, 95% CI 0.34–1.80).³⁴ Also, there did not appear to be any differences in perioperative complication rates (RR 0.99, 95% CI 0.60–1.64). However, the length of hospital stay was higher for the laparoscopic group by 1 day (mean difference 1 day, 95% CI 0.8–1.4). Although the operative times for the TVT procedures were shorter than for laparoscopy (mean difference 20 minutes, 95% CI 17–24), the procedural costs to the hospital appeared to be similar in both groups.^{40,41} However, Kilonzo et al demonstrated that in the short term, TVT was more cost-effective than laparoscopic or open Burch colposuspension.⁴⁵

It is important to note that one limitation of the Cochrane review is that most of the trials in the analysis had mean follow-up periods of no more than 18 months. Therefore, while in the short term, there appears to be a trend favoring self-fixing sling procedures, it is unclear whether these slings have any potential long-term benefits over laparoscopy. A recent long-term analysis of 10 randomized controlled trial with a mean follow-up period of 65 months demonstrated similar efficacy between TVT and laparoscopic Burch colposuspension.⁴⁶

LAPAROSCOPIC PROCEDURES FOR PELVIC ORGAN PROLAPSE

When considering the correction of POP, it is necessary to understand the basic three levels of pelvic organ support proposed by DeLancey⁴⁷ (Figure 74.4). The apex and upper fourth of the vagina is supported by the cardinal-uterosacral complex (level 1). Failure

of these supports due to breaks in the endopelvic fascia and uterosacral/cardinal ligaments is thought to result in uterine descensus or vaginal apical (vault) prolapse.⁴⁹ Furthermore, small bowel can herniate in this area resulting in an enterocele. The bladder, upper rectum, and middle aspect of the vagina are supported by the pubocervical and rectovaginal endopelvic fascia which attaches laterally to the ATRP and the medial aspect of the levator ani muscles (level 2).⁴⁷ A breach in these supports can result in anterior vaginal wall prolapse with or without paravaginal defects (cystocele, cystourethrocele, or urethrocele) and posterior wall prolapse (rectocele). The lower fourth of the vaginal support is fused to the perineal body (level 3). Defects in this support result in distal rectoceles and perineal descent. All pelvic support defects represent a break in the continuity of the endopelvic fascia and/or a loss of its suspension, attachment, or fusion to adjacent structures. The goals of pelvic prolapse surgery are to correct all defects and re-establish vaginal support at all levels resulting in the maintenance or restoration of normal visceral and sexual function.

Level I support

Uterosacral ligament vaginal vault suspension/enterocele repair and culdoplasty

Anatomy The anatomic landmarks during laparoscopic uterosacral ligament vault suspension and enterocele repair are the pubocervical fascia, the rectovaginal fascia, the uterosacral ligaments, and the ureter, which courses along the pelvic side wall and is approximately 1–1.5 cm

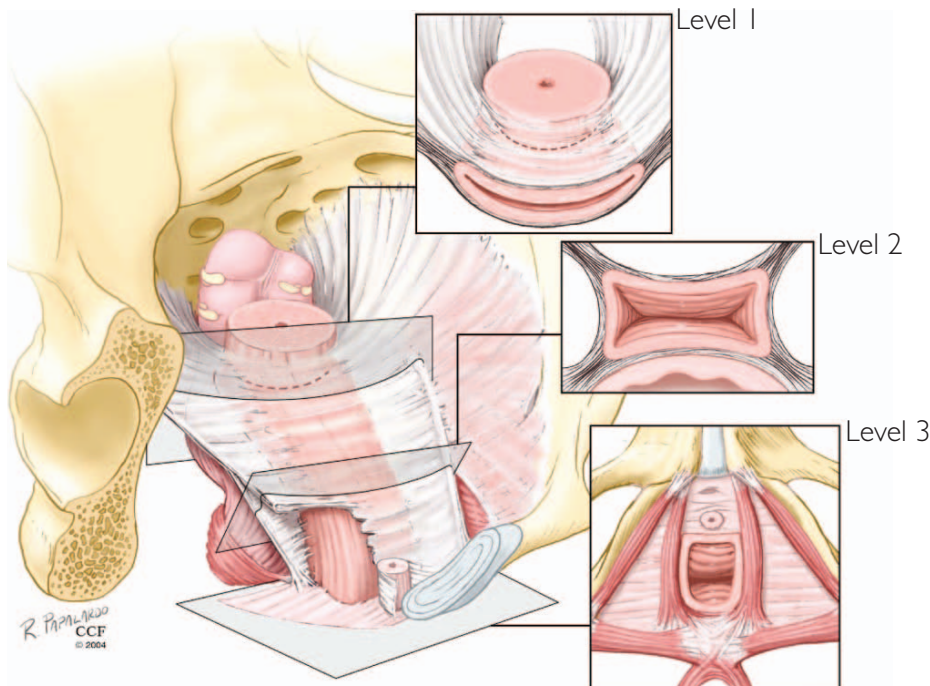


Figure 74.4 Pelvic floor supports. Level 1: The apex and upper fourth of the vagina are supported by the cardinal/uterosacral ligament complex. Level 2: The bladder, upper rectum, and mid vagina are supported by the pubocervical and rectovaginal endopelvic fascia which attaches laterally to the arcus tendineus fascia pelvis and the medial aspect of the levator ani muscles. Level 3: The lower fourth of the vaginal support is fused to the perineal body. From reference 48, with permission. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

lateral to the uterosacral ligament as it passes underneath the uterine artery.

Techniques The procedure consists of placement of non-absorbable suture through the full thickness of the uterosacral ligament at the proximal portion of its break or at the level of the ischial spine and reattaches it to the vaginal apex by incorporating the uterosacral-cardinal ligament complex and rectovaginal fascia, without going through the vaginal epithelium (Figure 74.5). One or two additional sutures can be placed through the uterosacral ligament proximal to the ischial spine resulting in further suspending the vaginal apex closer to the sacrum. This is done bilaterally and tied down individually. If concomitant enterocele repair is performed, sutures can first be placed to reapproximate the pubocervical and rectovaginal fascia resulting in obliterating the enterocele sac before resuspending the vaginal apex to the uterosacral ligaments. If the enterocele is large, excess vaginal tissue and peritoneum may first have to be excised. To prevent inadvertent ureteral kinking during the vault suspension, peritoneal incisions may be made lateral to the uterosacral ligaments to further separate the uterosacral ligaments away from the ureters.

In 1997, Ross described a modification of the uterosacral vaginal vault suspension which resulted in re-establishing the lateral and posterior pericervical rings of

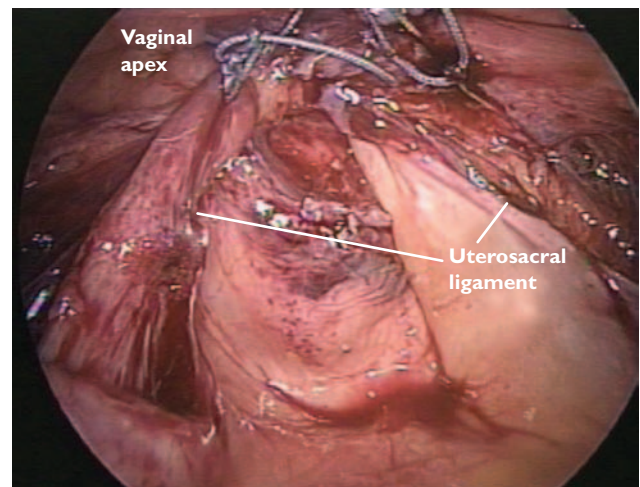


Figure 74.5 Laparoscopic uterosacral ligament vaginal vault suspension.

the endopelvic fascia by reapproximating the pubocervical fascia, rectovaginal septum, and cardinal/uterosacral ligaments.⁵⁰ After the peritoneum is dissected off the vaginal apex, and the pubocervical fascia and rectovaginal septum are identified, non-absorbable sutures are used to purse string the left and right uterosacral-cardinal ligament complex, the rectovaginal septum, and the posterior vaginal wall together. This suspension results in plication of bilateral uterosacral ligaments as well as prevention of any potential enterocele formation.

To obliterate the cul de sac, a Moschcowitz culdoplasty can be performed laparoscopically in the same manner as during laparotomy. A non-absorbable suture is placed in the peritoneum around the cul de sac in a purse string fashion and tied extracorporeally. Additional sutures are placed as needed. The ureters should be carefully examined during and after the Moschcowitz procedure. The peritoneum medial to the ureters may be incised to further dissect away the ureter in order to prevent inadvertent ureteral kinking.

The Halban procedure can also be performed laparoscopically by placing non-absorbable sutures starting at the posterior vagina and proceeding longitudinally over the cul de sac peritoneum and then over the inferior sigmoid serosa. These sutures are tied as they are placed. Sutures should be placed approximately 1 cm apart. There is little risk of ureteral compromise with this procedure; however, it is important to visualize the ureters after all sutures are tied.

Clinical results Although there are papers describing techniques of uterosacral vaginal vault suspension and enterocele repair or prophylaxis, there are few reported series on the clinical efficacy or complication rates following these procedures. Miklos et al followed a series of 17 patients who underwent laparoscopic uterosacral ligament vault suspension with vaginal enterocele repairs with or without site-specific rectocele repairs and found that two women had asymptomatic recurrent Baden-Walker grade 1 apical prolapse without any recurrent enterocele or rectocele after a mean follow-up of 6 months.⁵¹ Seman et al retrospectively assessed 73 patients who underwent different laparoscopic repairs depending upon the location of their genital prolapse with a mean follow-up period of 8 months.⁵² Specifically, 47 of those patients underwent laparoscopic uterosacral vaginal vault suspension with an objective success rate of 100%. Lin et al reviewed 133 patients who experienced laparoscopic uterosacral ligament vaginal vault suspension for uterovaginal or vaginal vault prolapse with a mean follow-up of 3.2 years and found that 17 patients (13%) had recurrent Baden-Walker grade 2 or greater apical prolapse.⁵³ Furthermore, Ostrzenski examined 27 women with posthysterectomy total vaginal prolapse who underwent laparoscopic uterosacral and cardinal ligament vault suspension with or without paravaginal defect repair and found more patients with recurrent apical prolapse in the group that did not undergo concomitant paravaginal defect repair.⁵⁴

In terms of laparoscopic culdoplasty, it is important to note that in a comprehensive review of 98

publications regarding open abdominal sacral colpopexy, Nygaard et al showed that concomitant culdoplasty did not improve success rates or decrease recurrence of vaginal apical prolapse.⁵⁵ Performing culdoplasty to repair or prevent enteroceles, Lyons and Winer noted no complications other than trocar site infections after reviewing 276 Halban or Moschcowitz procedures.⁵⁶ Cadeddu et al described a modified Moschcowitz procedure for treating symptomatic enteroceles in three patients and reported 100% success rates after a mean follow-up period of 11 months without significant operative complications.⁵⁷ Koninckx et al illustrated using the carbon dioxide laser for vaporization of the enterocele sac followed by uterosacral ligament shortening and suspension of the posterior vaginal wall in four women without significant complications.⁵⁸

Sacral colpopexy

Anatomy The anatomic landmarks of sacral colpopexy are the middle sacral artery and vein; the sacral promontory with the anterior longitudinal ligament; the aortic bifurcation and the vena cava, which are at the L4–L5 level; the right common iliac vessels and right ureter, which are at the right margin of the presacral space; and the sigmoid colon, which is at the left margin. The left common iliac vein is medial to the left common iliac artery and can be damaged during dissection or retraction.

Techniques Dissection of the peritoneum off the vaginal apex is performed to delineate the rectovaginal fascia. Anterior dissection is performed (taking care to avoid damage to the bladder) if mesh is to be sutured to the pubocervical fascia anteriorly or if enterocele repair is needed. A vaginal obturator, spongystick, or equivalent vaginal manipulator (EEA by Reusable Sizer Set, Autosuture, Norwalk, CT, or the CDH by Ethicon Endo-Surgery, Inc, Cincinnati, Ohio) is used for delineation of the vaginal apex or rectum. If exposure of the sacral promontory and presacral space is not adequate, the patient should be tilted to her left and/or a fan retractor (Origin Medsystems, Menlo Park, CA) or snake retractor (Snowden Pencer, Tucker, GA) can be used to retract the sigmoid colon. Alternatively, the sigmoid epiploica may be sutured laterally to retract the sigmoid colon to the left. The peritoneum overlying the sacral promontory is incised longitudinally and extended to the cul de sac. A laparoscopic dissector or hydrodissection is used to expose the periosteum of the sacral promontory. If blood vessels are encountered during the dissection, coagulation is used to achieve hemostasis. Pressure

application with a sponge placed through a 10 mm port can also be used and is usually successful in resolving most presacral bleeds.

Biologic graft or synthetic mesh is used to suspend the vaginal apex to the sacrum (Figure 74.6). This can be done with two separate pieces of mesh, one attached to the vaginal apex anteriorly and one posteriorly. After appropriate tensioning of the meshes separately, they are sutured together at the sacrum. Another method is to use a 'T' shaped mesh and incorporate one arm on the anterior vaginal apex and one arm posteriorly. Specifically, a 14 cm × 3.5 cm biologic graft or polypropylene mesh is sutured to the vaginal apex anteriorly with two to three pairs of non-absorbable sutures. Another mesh (14 cm × 3.5 cm) or the other arm of the 'T' shaped mesh (5 cm × 3.5 cm) is sutured to the vaginal apex and rectovaginal septum posteriorly with three to four pairs of non-absorbable sutures. Care is taken to place the sutures through the entire thickness of the vaginal wall, without incorporating the epithelium. After ensuring that there is no undue tension, the meshes are sutured to the anterior longitudinal ligament of the sacrum with two or three non-absorbable sutures. Titanium tacks or hernia staples may also be used instead to attach the mesh to the anterior longitudinal ligament. Excess mesh is excised. The peritoneum is reapproximated over the mesh with absorbable suture. If the mesh remains exposed, sigmoid epiploic fat may be used to cover the mesh.

Clinical results As open abdominal sacral colpopexy has been shown to have one of the highest long-term success rates (78–100%),⁵⁵ theoretically, if performed in a similar manner, laparoscopic sacral colpopexy should also result in similar success rates. However, to date, there has been no RCT comparing open with laparoscopic sacral colpopexy. Nezhat et al first reported a series of 15 patients who underwent laparoscopic sacral colpopexy with cure rates of 100% for apical prolapse after mean follow-up periods ranging from 3 to 40 months.⁵⁹ There was one case of conversion to laparotomy for presacral hemorrhage. Lyons and Winer described a series of four laparoscopic sacrospinous fixations and ten laparoscopic sacral colpopexies with decreased intraoperative and postoperative morbidity but comparable operative times to vaginal and abdominal approaches.⁵⁶ They attributed the decrease in morbidity of the laparoscopic route to improved visualization and superior anatomic approach. Both of the above series used mesh and either sutured or stapled the mesh onto the longitudinal ligament of the anterior sacrum.

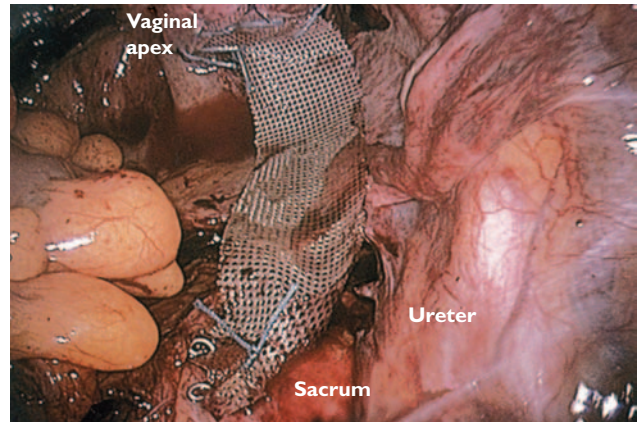


Figure 74.6 Laparoscopic abdominal sacral colpopexy with polypropylene mesh attached on the anterior and posterior vaginal apex and sacrum.

Ross reported on 19 patients with posthysterectomy vaginal apical prolapse who underwent laparoscopic sacral colpopexy, Burch colposuspension, and modified culdoplasty with or without paravaginal defect repair and posterior colporrhaphy as indicated.⁶⁰ The author found a cure rate of 100% for apical prolapse and 93% for stress urinary incontinence after 1 year with two patients who were lost to follow-up. Two patients had recurrent paravaginal defects and three patients had recurrent rectoceles that were less than Baden-Walker grade 2. Vaginal length ranged from 10.8 to 12.1 cm and all sexually active patients reported no sexual dysfunction. There were seven complications: three cystotomies, two urinary tract infections, one seroma, and one inferior epigastric vessel laceration. In another series, Ross prospectively assessed 51 patients who underwent laparoscopic sacral colpopexy for Baden-Walker grade 3 or 4 apical prolapse and found cure rates of 93% after 5 years in 43 patients.⁶¹ In three patients with recurrent prolapse, the polypropylene mesh was found to be detached from the vaginal apex. Complications included two patients with partial small bowel obstructions secondary to bowel adherence to the mesh and four cases of mesh erosion into the vagina, two of which resolved with conservative management and two required vaginal flaps to cover the mesh.

Gadonneix et al used two separate pieces of mesh for laparoscopic sacral colpopexy with or without Burch colposuspension in 46 patients and found recurrent rectoceles in 12% of patients after a mean follow-up of 24 months.⁶² Interestingly, recurrent rectoceles only occurred in patients who underwent laparoscopic

Burch colposuspension along with the colpopexy ($p = 0.036$). Intraoperative complications included cystotomies in 7% of patients, all of which were repaired laparoscopically. Apart from recurrent prolapse, the only postoperative complications were de novo urge incontinence in two patients and obstructive defecation in one patient thought secondary to excessive mesh tension. Cosson et al reviewed 83 patients who underwent laparoscopic sacral colpopexy and found that one patient required reoperation for recurrent anterior prolapse (cystocele) after a median follow-up of 11 months.⁶³ The authors performed concomitant laparoscopic supracervical hysterectomy in 60 patients and converted six cases to laparotomy due to technical difficulties. Three patients required reoperations for hemorrhage or hematoma. There was one rectal and two bladder injuries. Operative time was found to decrease from 292 to 180 minutes with increased experience.

At the Cleveland Clinic, we compared 56 laparoscopic with 61 open abdominal sacral colpopexies and found comparable clinical outcomes with reoperations for recurrent prolapse in six and three patients, respectively, after mean follow-up of 14 months and 16 months, respectively.⁶⁴ Five out of six patients in the laparoscopic group who required reoperations did so for recurrent posterior compartment prolapse (rectoceles). The laparoscopic approach required a significantly longer operating room time of 269 minutes compared with 218 minutes abdominally ($p < 0.0001$) but shorter mean hospital stay period of 2 days compared with 4 days ($p < 0.0001$). Although the study was not powered to investigate this, there were no differences in complication rates between the abdominal or laparoscopic approach.

One of the largest published series of laparoscopic sacral colpopexy (140 patients) with the longest median follow-up period (66 months) found an anatomic apical cure rate of 92% (61 patients out of the 66 patients that were available for examination).⁶⁵ Recurrent prolapse in the other compartments was found in 23 (66%) of patients with equal numbers of anterior and posterior recurrences. Of the patients 79% (81/102) thought that their symptoms of prolapse were 'cured' or 'improved'. The mesh erosion rate was 9%.

Sacrohysteropexy (sacrocolpopexy)

This procedure is performed in a similar manner to the sacral colpopexy except that the mesh is only attached to the posterior aspect of the vaginal wall.

The dissection involves opening the rectovaginal space with posterior attachment of a piece of graft or mesh as described above. The mesh is also attached to the posterior cervix to the level of the internal os. After appropriate tension, the mesh is sutured to the sacrum as above and reperitonealized. To date, there are no published series addressing the efficacy or complications associated with laparoscopic sacrohysteropexy.

Robotic assisted laparoscopy

Despite the advantages over laparotomy, most of the above laparoscopic procedures have not been widely adopted. This could be secondary to the steep learning curve associated with certain laparoscopic techniques such as suturing as well as the potentially longer operative time when compared with the open approach. Therefore, some surgeons have advocated using the robot to perform these laparoscopic procedures. Robotic systems were developed with the rationale of enhancing laparoscopic movements by making them more ergonomic, easier to perform, and more precise. Robotic systems also offer perception of depth provided by a three-dimensional monitor. Specifically, with the da Vinci Surgical System (Intuitive Surgical Inc, Sunnyvale, CA), there are endowrist instruments that are capable of 7° of movement that mimic the human wrist and are controlled intuitively at the surgeon's console.⁶⁶ Suturing at awkward angles secondary to the fulcrum effect associated with conventional laparoscopy is eradicated. The need for a skilled surgical assistant to improve the efficiency of advance laparoscopic procedures like sacral colpopexies is also minimized as only one surgeon can operate on the console at one time. Other advantages are that robotic surgery is also less stressful on the body because the surgeon sits comfortably at the operator's console, looking through a three-dimensional monitor, using only hands and wrist action to manipulate the robotic arms. The surgeon also has the ability to operate from a remote site. Robotic assisted procedures involve the same steps as laparoscopic procedures with the above advantages.

Clinical results To date, there is one published series from the Mayo Clinic addressing robotic assisted laparoscopic sacral colpopexy in 30 patients and it found two patients with recurrent prolapse (one rectocele, one vault) and two with mesh extrusions out of the 21 patients who had a mean follow-up of 24 months.⁶⁷ Mean operative time was 186 minutes.

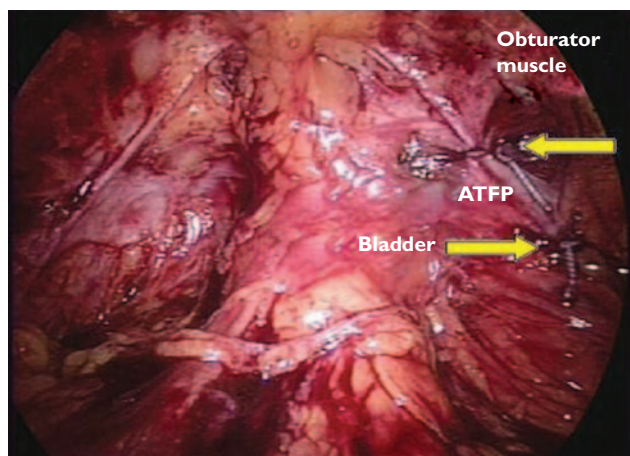


Figure 74.7 Laparoscopic paravaginal defect repair with sutures reapproximating the defect (arrows). ATFP, arcus tendineus fascia pelvis.

Level 2 support (anterior)

Laparoscopic paravaginal defect repair

Anatomy and techniques Important anatomic landmarks and dissection into the space of Retzius involved in laparoscopic paravaginal defect repair are similar to those of Burch colposuspension described previously. The specific procedure of paravaginal defect repair includes the placement of non-absorbable sutures through the full thickness of the vagina (excluding the vaginal epithelium) starting at the lateral vaginal fornices, and then into the ATFP, which is 3–4 cm below the obturator fossa (Figure 74.7). This is then tied extracorporeally. An additional three to five sutures are placed in a similar manner at 1–2 cm intervals until the paravaginal defect is closed. The procedure is performed bilaterally.

Clinical results Ostrzenski prospectively assessed 28 patients who underwent laparoscopic paravaginal defect repair for genuine stress incontinence with a cure rate of 93% based on objective and subjective data.⁶⁸ The mean operative time was 165 minutes and there were no significant perioperative complications. Speights et al retrospectively examined 171 subjects who underwent laparoscopic Burch colposuspension with or without paravaginal defect repair and found a 2.3% bladder injury rate which is in contrast to the 10% lower urinary tract injury rate reported for open Burch procedures.⁶⁹ This difference is thought to be due to the decrease in blood loss and improved visualization afforded by the laparoscopic approach.

Level 2/3 support (posterior)

Laparoscopic rectocele repair

Anatomy and techniques The anatomic landmarks of laparoscopic rectocele repair are the rectovaginal septum, its lateral attachment to the medial aspect of the levator ani muscles, and the perineal body inferiorly. The rectovaginal peritoneum is sharply incised and a combination of blunt dissection, sharp dissection, or hydrodissection may be used to open the rectovaginal space down to the rectovaginal septum. Defects within the rectovaginal septum are repaired with non-absorbable suture or can be reinforced with mesh. If part of the defect involves separation of the rectovaginal septum from the iliococcygeus fascia, this can be reconnected with non-absorbable suture. Furthermore, for high rectoceles or enteroceles, a mesh or graft can be used to attach the rectovaginal septum to the uterosacral ligament. Plication of the levator ani muscles may also be performed laparoscopically with care taken to avoid a posterior vaginal ridge as this may lead to dyspareunia.

Clinical results Laparoscopic posterior defect (rectocele) repairs are infrequently undertaken as traditional repairs performed vaginally have yielded success rates of 76–96% with low rates of complications.⁷⁰ Lyons and Winer prospectively evaluated 20 patients who underwent laparoscopic rectocele repair with polyglactin mesh with or without concomitant hysterectomy and found that 16 patients had resolution of symptoms at 1 year.⁷¹ The mean operative time for the rectocele repair portion was 35 minutes. Estimated blood loss was minimal and hospital stay was less than 24 hours.

CONCLUSION

There is level 1 evidence that demonstrates similar efficacy between laparoscopic and open Burch colposuspension with follow-up periods ranging from 6 months to 5 years with decreased complication rates and recovery periods in the laparoscopic group.³⁴ The traditional placement of two sutures on either side of the urethra appears to result in better outcomes than using only one suture or using mesh. There is also level 1 evidence that demonstrates self-fixing mid-urethral slings such as TVT Ethicon women's Health and Urology and SPARC result in higher objective cure rates than laparoscopic Burch colposuspension with similar complication rates over a follow-up period of 18 months. However, this benefit may not be present in the long term.

Most of the literature addressing the efficacy of laparoscopic procedures to correct POP consists of

case series by expert surgeons with many studies centered on sacral colpopexies. Therefore, it is difficult to make valid comparisons between published series or clear statements regarding the efficacy of procedures. Furthermore, there exist multiple variations in laparoscopic techniques of standard procedures in prolapse surgery. It is often unclear whether these small or large variations have an impact on anatomic or functional outcome. Additionally undergoing laparoscopic repair of POP patients will often receive concomitant vaginal procedures. Therefore, it is difficult to make any definitive statements regarding the efficacy of a specific technique in isolation without taking into account the additional procedures that were performed. Finally, due to the lack of consensus on the definition of anatomic cure and a deficiency of validated questionnaire usage to document functional outcomes, it is challenging to properly compare success rates in different trials.

Despite the above limitations and lack of RCTs, there is growing interest in laparoscopic correction of POP due to patient desires and increased availability and marketing of other minimally invasive surgical techniques such as vaginal mesh procedures using commercial kits. However, laparoscopic approaches for prolapse surgery are still not widely adopted partially secondary to the technical difficulties involved with certain laparoscopic techniques such as suturing.⁷² Therefore, there has also been recent interest in using robotic assistance in performing these procedures laparoscopically in order to bypass the steep learning curve, especially for novice laparoscopic surgeons.

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75 Laparoscopic surgery for vesicovaginal fistulas

Rene Sotelo and Anthony Finelli

INTRODUCTION

In developed countries, vesicovaginal fistula (VVF) is often a complication of urogynecologic surgery. Abdominal hysterectomy is the most common cause of VVF, estimated to occur in one in 1800 procedures.¹ Radiation therapy and obstetric traumas are other known causes of VVF. The actual cause of fistula formation postoperatively is not clearly understood, but is usually related to bladder injury. The diagnosis is often made 1–3 weeks postoperatively with the most common presentation being persistent vaginal leakage. Other symptoms include hematuria, fever, vaginal or suprapubic pain, and a history of recurrent cystitis. The diagnosis is confirmed with some form of oral (pyridium) and/or intravesical dye (methylene blue) resulting in vaginal tampon discoloration. The combination of oral and intravesical dye can be used to differentiate vesicovaginal from ureterovaginal fistula or identify the coexistence of these fistulas. Axial imaging with intravenous contrast or an intravenous pyelogram should be used to further assess the possibility of a concomitant ureterovaginal fistula. Cystoscopy and further diagnostic testing may be required to localize the fistula and rule out ureterovaginal fistula.

An initial trial of conservative treatment is appropriate, but success is infrequent (7–12%).¹ Conservative measures include bladder drainage with a catheter, and anticholinergics and antibiotics when indicated. If a small fistula is identified, fulguration with prolonged bladder drainage can be attempted. Definitive treatment often requires surgical intervention. Primary surgical repairs of VVF that occur secondary to surgery are successful in 75–97% of cases.¹ Secondary repair after an initial failed correction is successful in 90% of patients.^{2,3}

The basic principles of laparoscopic VVF repair include adequate exposure, excision of fibrous tissue from the edges of the fistula, tension-free approximation of the tissue edges, suitable suture materials, tissue interposition, and postoperative bladder drainage. Several surgical techniques have been described and each offers distinct advantages. However, controversy still exists over the ideal approach and time of repair.

Vesicovaginal fistula may be treated with different surgical techniques applied transvaginally and/or transabdominally. Surgeon preference is often part of the decision making process.^{4–6} In general, a vaginal approach is associated with less morbidity, diminished blood loss, and less postoperative bladder irritability. Furthermore, it may be performed in an outpatient setting and often with results equal to those achieved with an abdominal approach.⁷ An abdominal approach is indicated when another intra-abdominal condition requires simultaneous surgical attention or in situations where the fistula is high lying and/or the vaginal vaults preclude a vaginal approach.⁷

Laparoscopy can be an alternative to the abdominal approach for managing VVF. Nezhat et al⁸ initially reported laparoscopic VVF repair in 1994. Several other reports followed building on this initial experience.^{2,4,9–13} Advantages of laparoscopy in general include magnification of the operative field, hemostasis, decreased hospital stay, and a shorter convalescence.

SURGICAL TECHNIQUE

After general anesthesia is administered, the patient is placed in low lithotomy. Cystoscopy is performed and both ureters are cannulated with 5Fr ureteric catheters. This facilitates identification of the ureteral orifices and provides a sense of the ureters' course. A ureteral catheter of different color is introduced through the bladder, advanced along the fistulous tract into the vagina and retrieved at the introitus. For large fistulas, a Foley catheter can be used in place of a 'ureteral' catheter. Access is gained at the umbilicus and a 10mm port inserted. A standard five-port transperitoneal approach, similar to that employed in laparoscopic prostatectomy, is used. A sponge retractor is inserted into the vagina via the introitus. This is then used to retract the vagina posteriorly. The posterior bladder wall is incised vertically and dissection carried vertically toward the fistula. A cystoscope can be inserted and used to provide endoscopic light guidance to the fistula. However, once the bladder is

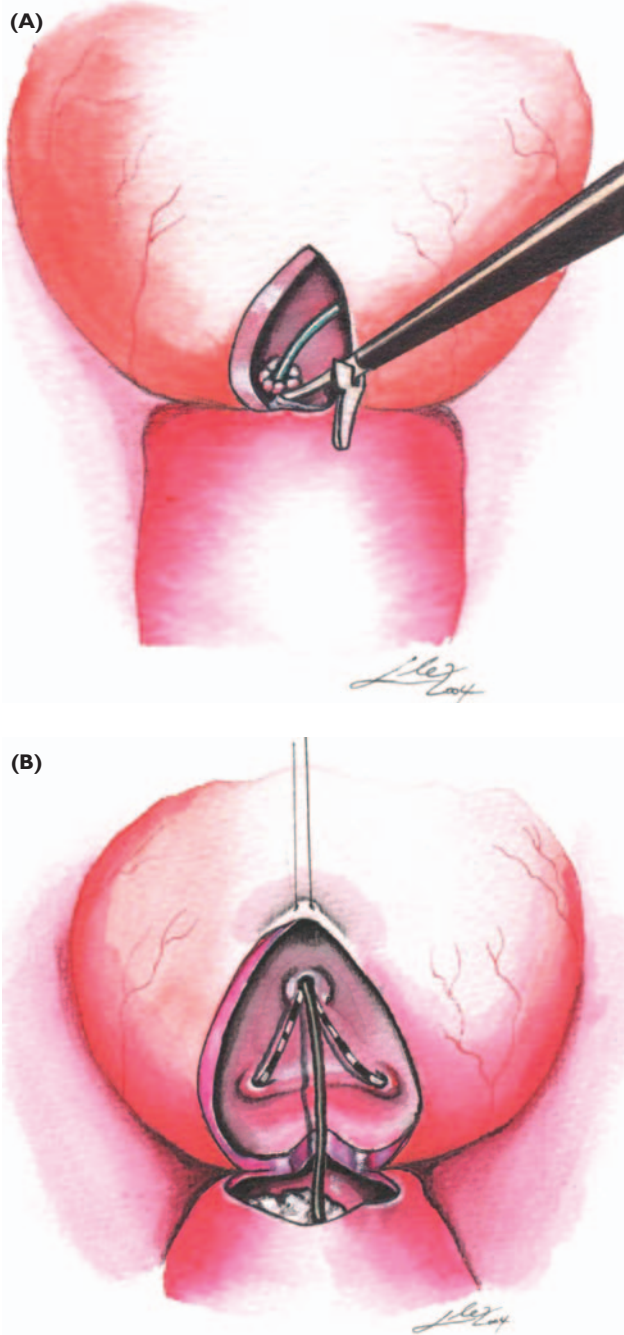


Figure 75.1 Bladder and vagina are open demonstrating ureteric stents and stented fistula. (A) Anterior view. (B) Sagittal view.

opened the tract is usually visualized particularly because it has been catheterized. The incision is carried deep until the posterior aspect of the catheter and vaginal sponge retractor are exposed (Figure 75.1). When communication between the vagina and bladder is apparent, the sponge retractor is withdrawn and a pack is placed in the vagina to prevent loss of pneumoperitoneum. Dissection is continued until the fistula is completely separated from the vagina. The

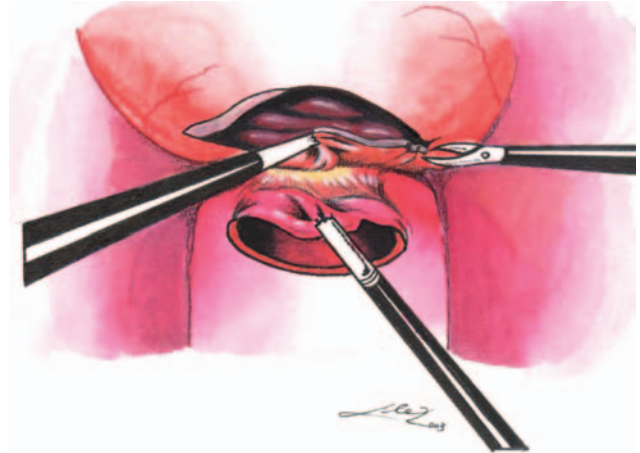


Figure 75.2 'Flaps' are created for adequate tension-free closure of the bladder and vagina.

fibrous tissue edges of the fistula are excised sharply with laparoscopic scissors. Further dissection is performed with laparoscopic scissors to create 'flaps' for adequate tension-free closure of the bladder and vagina (Figure 75.2).

The bladder is closed beginning at the distal apex and running a 2-0 polyglactin on a CT-1 needle. The suture is run in a superior fashion and cystoscopic guidance can be used to facilitate the closure. An additional running closure of the bladder serosa is performed with absorbable suture. The bladder is then filled with saline to confirm a watertight closure. The vagina is then closed similarly with a running 2-0 polyglactin on a CT-1 needle, but transversely. Next, a suture is placed in the anterior wall of the vagina distal to the closure. This is used to anchor the tissue that has been harvested for interposition (Figure 75.3). Omentum, if available, or an appendix epiploic can be used.

An 18Fr urethral catheter is then inserted to maintain bladder drainage. A suprapubic cystostomy tube is not utilized. A drain is placed in the pelvis. The drain is usually removed on the 2nd postoperative day. The urethral catheter is removed 10 days postoperatively. A cystogram may be performed to confirm the integrity of the bladder wall. Patients are advised not to use tampons and refrain from sexual intercourse for 6–8 weeks.

OUTCOMES

In our initial report, 15 patients were treated with this technique.¹² Since this initial experience we have continued to use this as our standard approach to the surgical correction of vesicovaginal fistula. In our initial series, 11 patients were primary repairs, and four

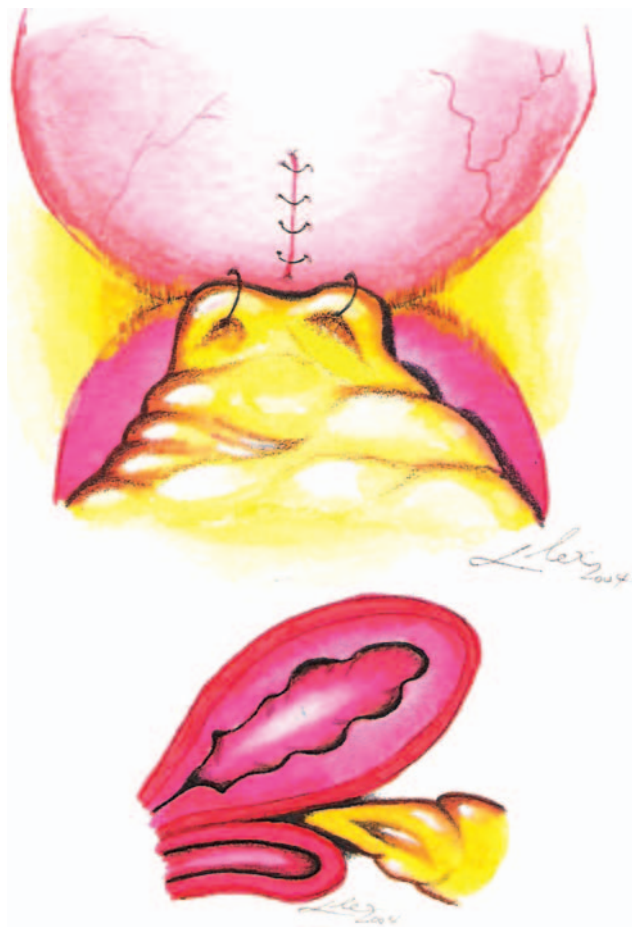


Figure 75.3 Interposition flap anchored to vaginal closure.

were secondary. Additionally, one of the patients required concomitant ureteral reimplantation and another nephroureterectomy. Although adding complexity, these ancillary procedures can be performed laparoscopically at the same sitting. After a mean follow-up of 27 months, one patient had developed a recurrent fistula.

CONCLUSIONS

Laparoscopic vesicovaginal fistula repair is feasible and associated with distinct advantages. Although direct

comparisons to an open transabdominal or vaginal approach are lacking, preliminary data suggest that this technique is at least as effective and is potentially associated with less morbidity. Advanced laparoscopic skill, with the ability to perform intracorporeal suturing, is necessary to complete this operation efficiently and effectively.

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76 Arterial surgery for erectile dysfunction

Jonathan P Jarow

INTRODUCTION

Erectile dysfunction (ED) is an extremely common disorder that affects at least one in three men during their lifetime. The Massachusetts Male Aging Study demonstrates that although the prevalence of ED increases with age, men of all age groups are affected.¹ In addition, when all degrees of ED are included, almost 70% of elderly men complain of this disorder. During the past two decades many new and effective medical therapies for the management of ED have been introduced. Largely due to the availability of many new and safe medical therapies, the management of ED has evolved into a goal-oriented process whereby after minimal evaluation, men choose their therapy amongst a menu of options. In this setting, the underlying etiology of their ED is rarely determined since it has been shown to have little impact upon management. Yet, these medical therapies are palliative since they often require lifelong use to maintain sexual function. The attraction of penile vascular surgery is that this treatment modality is potentially curative.

The underlying etiologies of ED may be classified as psychogenic, endocrinologic, neurogenic, and vasculogenic. Patients with psychogenic ED may be cured through sex therapy and the rare patient with a pituitary endocrine disorder may be cured via either dopamine agonists or pituitary surgery. Unfortunately, neurogenic disorders are not reversible and the vast majority of patients with vascular pathology are not amenable to arterial reconstructive surgery. Despite numerous case series reported in the literature, the evidence supporting the use of penile arterial reconstructive surgery is insufficient for a recommendation for its application in even the highly selected ED patient according to the 2005 AUA Best Practice Policy guidelines.² This chapter describes patient selection that may optimize the outcome and how to perform penile arterial reconstructive surgery.

PENILE ANATOMY AND PHYSIOLOGY

Anatomy

The anatomy and physiology of an erection as it pertains to penile arterial reconstructive surgery is reviewed

here. The human penis is comprised of three cylinders surrounded by fascia (Buck's) and skin. The paired erectile bodies, corpora cavernosa, are composed of a vascular sinusoidal tissue surrounded by a strong elastic covering, tunica albuginea. The third cylinder, corpus spongiosum, contains the urethra and creates the glans penis. The arterial blood supply is normally derived from the internal iliac artery through the internal pudendal artery, bilaterally. The internal pudendal artery exits the bony pelvis through Alcock's canal and the scrotal artery is the first branch followed by the urethral branch. The common penile artery then splits to form both the dorsal and cavernosal arteries. The cavernosal artery is the primary source of blood flow to the corpora cavernosa, however, variations from 'classic' arterial anatomy are quite common and textbook anatomy has been observed in as few as 20% of men undergoing pudendal arteriography (Table 76.1).^{3,4} The most common arterial anatomic anomalies are crossing cavernosal arteries and distal perforators from the dorsal artery. The venous anatomy also varies frequently. The nerve supply of the penis is twofold. Afferent sensory neurons travel in the paired dorsal nerves of the penis located lateral to the paired dorsal arteries. These nerves join the pudendal nerve within Alcock's canal. Autonomic nerves responsible for stimulation of an erection originate in the nervi erigentes in the pelvis. These nerves are located between the posterolateral prostate and rectum, then just lateral to the membranous urethra, and finally enter the corpora with the cavernosal arteries and veins within the hilum of the penis.

Physiology

A normal human erection is dependent upon an intact neuroendocrine system, adequate arterial blood flow, compliance of sinusoidal tissue within the corpora, and an intact veno-occlusive mechanism. A normal endocrine milieu with adequate levels of circulating androgens and low levels of prolactin appears to be important for normal erectile function. During the flaccid state of the penis the smooth muscles lining the sinusoidal spaces and the arteries are tonically contracted. The primary event in the production of a human erection appears to be non-adrenergic, non-cholinergic

Table 76.1 Variations of penile arterial anatomy documented by arteriography in men with erectile dysfunction

Variant	Jarow et al, 1993 ³	Bookstein and Lang, 1986 ⁴
Dorsal penile-cavernosal perforators	29%	91%
Accessory cavernosal branches	29%	57%
Bilateral cavernosal arteries arising from one penile artery	41%	13%
Bilateral absence of cavernosal arteries	2%	4%
Aberrant origin of the cavernosal	12%	9%

(NANC) stimulation of vascular endothelium synthesis of NO, which causes smooth muscle relaxation of the sinusoidal tissue within the corpora and penile arteries. Blood flow into the corpora increases dramatically and the sinusoids expand as they fill with blood. During the early filling stage the venous drainage of the corpora is unimpeded. As the sinusoids expand, the emissary veins are compressed on the underside of the tunica albuginea and passively occluded. During the latter portion of the filling phase, the penis becomes engorged and eventually becomes rigid as intracorporeal pressure reaches and exceeds mean arterial blood pressure. Patients with impaired arterial blood flow but a normal veno-occlusive mechanism will take longer to fill but may be able to achieve adequate rigidity. During a full erection, the arterial blood flow is reduced but still higher than during the flaccid state. Intracorporeal pressures are transiently higher than arterial blood pressure due to bulbocavernosus muscle contraction around the corpora. Orgasm and ejaculation are accompanied by adrenergic release which is the stimulation of detumescence. Release of alpha-adrenergic neurotransmitters during ejaculation stimulates vascular smooth muscle contraction within the corpora. Experimental studies have shown that the norepinephrine is responsible for detumescence. This is why alpha agents such as phenylephrine are so effective at reversing the effects of pharmacologically stimulated erections. In addition, endogenous catecholamines released by the adrenals in response to anxiety can interfere with a patient's response to pharmacologically stimulated erection. Thus anxiety, 'clinic effect', can produce artifactual results during assessment of the vascular system.

VASCULAR EVALUATION

The key component in penile reconstructive surgery is patient selection. The ideal candidate for this procedure is a healthy patient with segmental occlusion of the penile arteries due to a traumatic injury rather than atherosclerosis. The evaluation of potential candidates

should not be limited to the finding of deficient arterial blood flow since failure will occur if there is not adequate run-off distal to the vascular anastomosis or if there is corporeal fibrosis that prevents veno-occlusion. Arterial blood flow is one of many critical components necessary for the production of a human erection. The human penis is dependent upon adequate arterial inflow and a normal veno-occlusive mechanism in order to achieve intracorporeal pressures sufficient to provide adequate rigidity for sexual intercourse. Absolute normal values for arterial blood flow and venous occlusion do not exist. Adequate levels of arterial inflow for one individual may not be sufficient for others, depending upon factors such as penile volume, autonomic tone, and degree of venous leakage. Conversely, patients with inadequate arterial blood flow will fail to fill the sinusoids and demonstrate 'venous leakage' since the veno-occlusive mechanism is a passive event. These factors should be kept in mind during the vascular evaluation.

There are very few indications for a complete vascular evaluation and most patients treated for ED should not undergo vascular testing. The principal indication for a complete arterial evaluation is to determine whether a patient is a candidate for penile revascularization. Therefore, the majority of patients undergoing this evaluation are younger (less than 50 years old), do not smoke, and have risk factors suggestive of a correctable vascular etiology such as trauma or primary ED. Other indications include documentation of an organic etiology for insurance or medico-legal purposes, to establish a diagnosis before proceeding with insertion of a penile prosthesis, and because of a patient's desire to know the cause of his sexual dysfunction.

The traditional diagnostic test of the penile arterial blood supply is angiography. However, this is an invasive test with both false positive and false negative results depending upon the experience of the radiologists. The first tests utilized to non-invasively screen patients for arterial occlusive disease were penile Doppler and plethysmography but these have been abandoned since they are not very accurate. Today, most patients are screened with a pharmacologic erection

test in the physician's office and depending upon the results and physician preference will proceed to penile duplex ultrasonography or measurement of cavernosal artery occlusion pressures during dynamic infusion cavernosography. The occlusion pressure of the cavernosal arteries is determined after pharmacologic stimulation of an erection and the intracorporeal pressure is raised by intracorporeal infusion of saline until the artery is occluded and the Doppler signal disappears. Recent studies suggest that this method of arterial blood flow assessment is as accurate as duplex ultrasonography. However, cavernosometry is a complex and invasive test with limited availability.

My own approach to screening patients for arterial occlusive disease is to start with a pharmacologic erection test in the office. I utilize a relatively high dose of vasodilator (20–40 µg of prostaglandin E1 as a single agent or 0.5–1 ml of Trimix) on the first injection test. However, it is important to keep the patient in the office until the penis has become flaccid if they achieve a full erection in response to the drug in order to avoid the complications of a prolonged erection and priapism. A lower dose could be used on the initial test in order to avoid this complication with an increased dose on repetitive testing if they fail to achieve a full erection. The patient most likely does not have severe vascular disease if they achieve a full response and can usually be managed with medical therapy.⁵ Conversely, a patient who does not respond to high dose vasodilator may have arterial occlusive disease or veno-occlusive dysfunction. Unfortunately, anxious patients with psychogenic ED may not respond normally either. Self-stimulation in the office, repeated testing in the office, and repeated testing at home may help exclude most but not all patients with psychogenic ED. The next step in the management of patients who do not respond to vasodilators is to perform a duplex ultrasound evaluation of the penile arteries.

Duplex ultrasonography has been utilized to assess the arterial blood flow in many organ systems and was first applied to the evaluation of ED by Lue et al in the early 1980s.⁶ The main advantage of duplex ultrasonography is the real-time assessment of the arteries responsible for an erection (cavernosal arteries) after pharmacologic stimulation with vasodilators. Duplex Doppler detects the movement of red blood cells within vessels because of the Doppler shift in the wavelength of the ultrasound signal reflected from the tissues. The velocity of blood flow in the artery can be calculated by knowing the magnitude of the Doppler shift and the angle of incidence. Real-time ultrasonography is used to identify the blood vessel and gate the

signals from that specific vessel. Therefore, there is less interference from nearby blood vessels, which could potentially produce an inaccurate result. A significant advance in ultrasound technology is the addition of color. The computer software in the ultrasound machine arbitrarily assigns a color to the tissue being imaged based upon the direction of the Doppler shift and varies the hue based upon the velocity of that movement. The addition of color assists in the identification of blood vessels during real-time ultrasonography but does not affect the measurement of blood flow velocity. The use of color flow provides great assistance in the identification of intrapenile arterial anatomic anomalies.⁷ The actual blood flow in a specific vessel can be calculated based upon time-averaged velocity and cross-sectional area. However, absolute values for penile arterial blood flow are not utilized since it is impossible to assess all of the arteries at a location outside the corpora before they have branched.

A penile duplex ultrasound study is comprised of ultrasonographic imaging of the corpora before and after administration of a vasodilator agent. It is important to perform this test with a maximal dose of vasodilator in a patient who has already failed a previous pharmacologic erection test. The corpora are initially assessed for scarring, plaques, and anomalous arterial blood supply. The cavernosal artery diameter is measured close to the base of the penis before and after pharmacologic stimulation. One of the key indicators of normal arterial blood flow is the presence of arterial pulsations on real-time ultrasonography after administration of a vasodilator. The alterations of hemodynamic parameters after pharmacologic stimulation undergo a characteristic time course that varies amongst patients depending upon the presence of vascular pathology and degree of patient anxiety. The best time to evaluate the penile arteries is during the filling phase that lasts for approximately 7–10 minutes following injection of vasodilator in a normal individual. The filling phase can take longer in a patient with arterial or veno-occlusive disease or be much quicker in a patient with neurogenic ED. Therefore, it is critical to be able to complete the assessment of the penile arteries within the first 10 minutes following administration of the vasodilator. The cavernosal artery diameter is reassessed at the same location as before and the peak blood flow velocity is measured in each artery. A normal result in the first 10 minutes is a reliable indicator of the absence of significant arterial occlusive disease. Care should be taken to be certain that an abnormal result is not artifactual. Pressing too hard with the transducer can partially occlude the

artery and produce a false low velocity measurement. Repeat examination after self-stimulation may be necessary to reveal a normal response in an extremely anxious patient. A delay in the measurement of blood flow velocities in a patient with a fast response may result in an erroneous diagnosis because blood flow velocity is normally reduced during a full erection. It is also important to look for alternative sources of penile blood flow in patients with an abnormal result. The most common vascular anomaly producing a false result is a distal perforator from the dorsal artery.

There has been a great deal of debate regarding the accuracy of duplex ultrasonography and the definition of a normal study. Several studies have been published comparing duplex ultrasonography with arteriography with mixed results.^{3,8-10} The interpretation of these studies depends upon the experience of the investigators with duplex ultrasonography and arteriography and how they decide to settle disputes between the results of the two studies. It is clear that duplex ultrasonography is the most accurate non-invasive imaging modality for the assessment of the intrapenile arteries. Several studies have attempted to define normal and adequate penile arterial blood flow. It appears that the visualization of pulsations and the peak blood flow velocity are the best indicators of normal arterial blood flow.¹¹ Normal men have peak blood flow velocity within the cavernosal arteries of greater than 35 cm/s, and greater than 25 cm/s is probably adequate.¹² Dilatation of the cavernosal arteries of at least 80% is considered adequate but is not as good an indicator of the presence of vascular disease as peak blood flow velocity. One of the main reasons for an inaccurate result of a duplex ultrasonography study is the presence of penile arterial anomalies. Approximately 80% of men with ED have anomalous penile arterial anatomy.⁴ Crossing cavernosal arteries and distal dorsal artery perforators are frequent anomalies. Knowledge of these possible anatomic variations and assessment of total blood flow velocity rather than assessing each side individually helps avoid misinterpretation of a duplex ultrasound study.

A pudendal arteriogram is the final step in the preoperative evaluation of a patient with arterial occlusive disease. The purpose of the arteriogram is twofold. The first is to document the presence and location of an occlusive arterial lesion. The second is to obtain a road map of the penile arterial vasculature as well as potential donor arteries for the surgical reconstruction. The arteriogram is performed in the standard manner using Seldinger technique with access through the right femoral artery. Bilateral flush

oblique aortogram studies are performed to assess the inferior epigastric arteries and rule out an anomalous derivation of the pudendal arteries. A selective study is then performed as distally as possible following intracorporeal administration of vasodilator. Intravascular administration of vasodilator is not adequate to visualize the intrapenile arteries. The intrapenile arterial anatomy and presence of distal run-off determines whether a vascular reconstruction is feasible and which procedure should be employed. Evaluation of veno-occlusive dysfunction is optional in a patient with arterial occlusive disease and is discussed at length in Chapter 77.

ARTERIAL RECONSTRUCTIVE SURGERY

Arterial bypass

Patients with discrete proximal arterial lesions, good distal run-off, and no evidence of veno-occlusive disease are the best candidates for arterial bypass surgery. The choice of donor and recipient vessels is dependent upon the patient's anatomy and the surgeon's preference. However, the most common procedure performed is an anastomosis between the inferior epigastric and the proximal dorsal artery (Figure 76.1). An alternative donor vessel to the inferior epigastric artery is a reversed saphenous vein graft attached to the superficial femoral artery (Figures 76.2 and 76.3). An alternative to the dorsal artery is the cavernous artery.¹³ However, the location of the cavernosal artery within the corpora makes this approach more difficult than necessary. Preoperative arteriography is mandatory to establish the presence of a good donor vessel and to choose an appropriate recipient artery. Variant penile arterial anatomy is present in up to 80% of impotent men. Common variants include both dorsal arteries originating from the same penile artery and distal cavernosal perforators from the dorsal artery. Patients with classic penile arterial anatomy are best served by an end-to-end anastomosis to the proximal dorsal artery on the side of the lesion in order to maximize blood flow into the corpora. The presence of distal cavernosal perforators may require an end-to-side anastomosis to an intact dorsal artery or an end-to-end anastomosis to the distal portion of the dorsal artery in order to maximize blood flow into the corpora. An intraoperative arteriogram may be necessary if the preoperative arteriogram does not adequately visualize the intrapenile arterial anatomy.¹⁴

The procedure is performed with the patient in the supine position. A transverse or paramedian abdominal

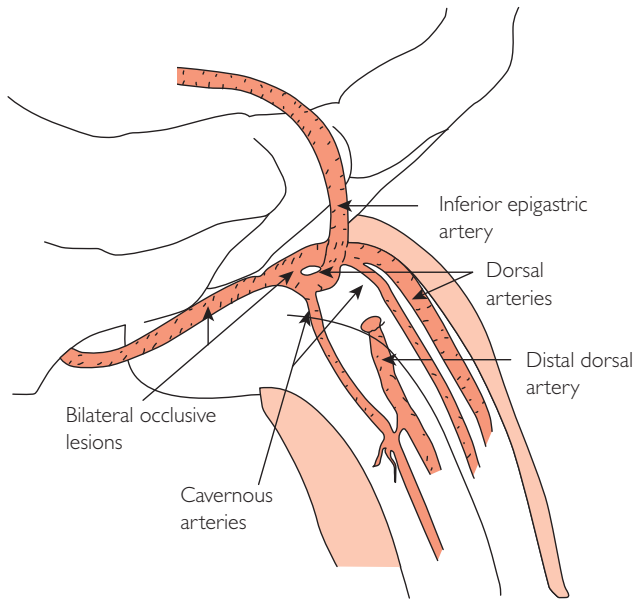


Figure 76.1 Schematic demonstrating the technique of direct end-to-end anastomosis of the inferior epigastric artery to the proximal dorsal artery of the penis. It is critical that the anastomosis be distal to the occlusive lesion and that the end of the dorsal artery is in communication with the cavernous artery or arteries. An intraoperative arteriogram may be necessary if the preoperative arteriogram did not adequately demonstrate the intrapenile arterial anatomy. If in doubt, an end-to-side anastomosis can be performed to the intact dorsal penile artery.

incision is performed in order to harvest the inferior epigastric artery. Alternatively, the inferior epigastric artery can be harvested laparoscopically.¹⁵ It is important to handle the donor vessel gently and avoid cautery close to the main trunk. Small arteriole side branches are frequent and should be managed with bipolar cautery. One or two vena comitantes run with the artery with numerous crossing branches that may be controlled with bipolar cautery. The artery is harvested to or just beyond the umbilicus from the underside of the rectus abdominis muscle. The inferior epigastric artery is usually still larger in diameter than the dorsal penile artery at this level. Systemic heparin (5000 units) is administered just prior to ligating the artery superiorly. A topical vasodilator such as bupivacaine is applied using a warm sponge and attention is turned to the penile vascular anatomy. A separate incision at the base of the penis is used to expose the dorsal penile arteries. A short pubic tunnel is created beneath the fascia of the anterior rectus sheath between the two incisions. The inferior epigastric vessels are passed through the tunnel with care not to twist or kink the artery. A segment of the dorsal artery is carefully dissected and prepared for anastomosis by stripping away loose tissue attached

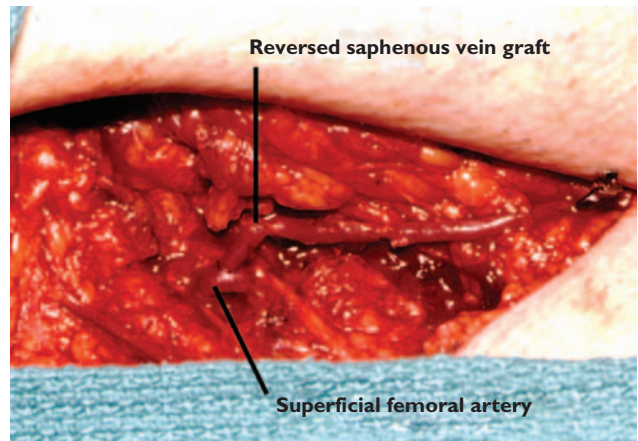


Figure 76.2 There are times when the inferior epigastric artery cannot be used as the donor artery due to either anatomic anomalies (early branching) or prior ligation from abdominal surgery. In this setting a reversed saphenous vein graft can be used. The donor site that is most convenient is the superficial femoral artery. Intraoperative photograph shows an end-to-side anastomosis between the saphenous vein and the superficial femoral artery.

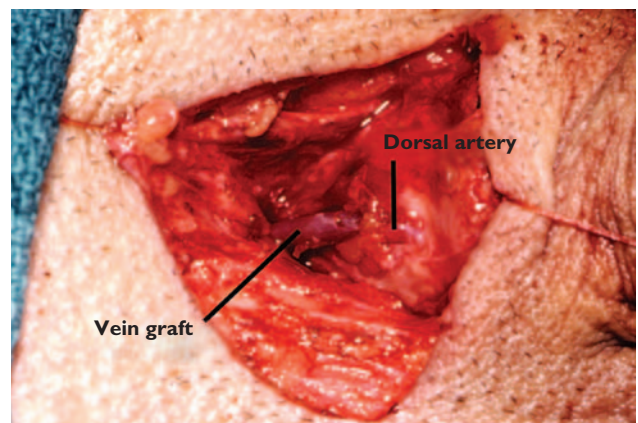


Figure 76.3 The reversed saphenous vein graft is then tunneled to a separate incision at the base of the penis where it is anastomosed to the dorsal artery. This is also performed in an end-to-side fashion using microsurgical technique.

to the adventitia. The operative microscope is then utilized to prepare the arteriotomies and perform the anastomosis. Because of the large relative size of the inferior epigastric artery compared with the dorsal penile artery, an end-to-end anastomosis is technically easier. An end-to-side may be necessary depending upon the pattern of penile arterial blood flow. The goal of the microsurgical revascularization is to direct blood flow into the corpora. An on the table intraoperative arteriogram of the penile arterial anatomy may be necessary in selecting the type and direction of the arterial anastomosis to maximize blood flow into the corpora. The anastomosis is performed using interrupted

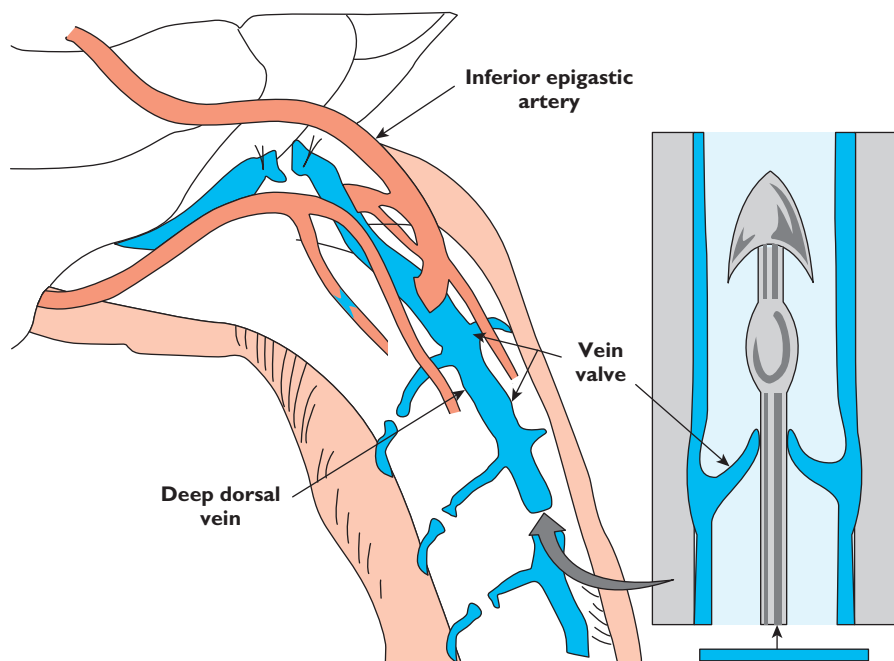


Figure 76.4 Schematic demonstrating the technique for arterialization of the dorsal vein using an inferior epigastric artery graft. It is important to disrupt the venous valves within the dorsal vein since they would prevent retrograde blood flow into the corpora. Disruption of the venous valves can be achieved using either a valvulotome or a Fogarty balloon catheter.

10.0 nylon suture on a tapered needle being careful to exclude adventitia from the lumen and to avoid tension on the anastomosis. Low molecular weight dextran (40%) is administered intravenously in a 100 ml bolus immediately upon completion of the arterial anastomosis and then maintained at 20 ml/hour for 5 days. The patient is also started on one aspirin daily. No further heparin is administered since there is a high complication rate associated with the combined use of heparin and dextran. A drain is placed for the abdominal incision. The patient should avoid cigarette smoke and foods containing vasoconstrictors. Sexual activity should not be performed for 6 weeks.

Arterialization of the dorsal vein

Arterialization of the deep dorsal vein to correct vasculogenic ED was first described by Virag et al.¹⁶ Virag has subsequently modified his procedure several times and other investigators have also suggested modifications (Figure 76.4). The procedure has been employed with limited success in patients with isolated veno-occlusive dysfunction, pure arteriogenic ED and patients with combined disease. This procedure theoretically impedes venous outflow through the deep dorsal vein at the same time as increasing intracorporeal arterial blood flow. Thus the balance between arterial inflow and venous outflow is significantly shifted to enhance penile engorgement. The patient is prepared in a similar manner to the straightforward arterial bypass operation.

The inferior epigastric artery is harvested through a separate abdominal incision as described above. The deep dorsal vein is isolated at the base of the penis through a separate incision. An isolated segment of the deep dorsal vein with its emissary veins intact should be prepared by ligating the deep dorsal vein both proximally near the hilum of the penis and distally prior to its trifurcation near the glans penis. The inferior epigastric artery is brought down through a tunnel beneath the fascia of the anterior rectus sheath. Again, it is important not to twist or kink this vessel. A venotomy is then created in the side of the deep dorsal vein. The deep dorsal vein has intact venous valves preventing retrograde flow into the corpora except in patients with massive venous leakage. These venous valves must be ablated in order for this procedure to have any significant benefit over simple ligation of the deep dorsal vein. A Leather valvulotome or Fogarty balloon catheter may be used to mechanically disrupt the valves. Alternatively, the valves can be excised through a venotomy using microsurgical techniques. All of these methods have the risk of damaging the vessel wall intima of the veins and resulting in eventual clotting of the anastomosis. In addition, disruption of the valves within the deep dorsal vein does not guarantee that blood flow will extend all the way into the corporeal sinuses. Therefore, valves of the emissary veins must be ablated as well. The anastomosis between the inferior epigastric artery and the deep dorsal vein is performed in an end-to-end or end-to-side fashion using interrupted 10.0 nylon sutures.

The overall success rate of this procedure has been disappointing. Modifications of this procedure have been developed to improve the success rate. Virag has described a modification where a window is created in the corpora by excising an ellipse of tunica albuginea. The arterialized segment of the dorsal vein is then anastomosed to the corpora in a side-to-side fashion in an effort to increase the blood flow directed into the corpora. Alternatively, Hauri¹⁷ has described a technique whereby the dorsal artery is anastomosed side-to-side to the arterialized dorsal vein segment in an effort to increase blood flow and maintain patency of the anastomosis (Figure 76.5).

Postoperative management

Postoperative management includes placement of a drain and systemic anticoagulation as described for the arterial bypass procedure. The patient should avoid cigarette smoke and foods containing vasoconstrictors postoperatively. Sexual activity should be delayed for at least 6 weeks to avoid disruption of the anastomosis. A major complication of this procedure is hypervascularity of the glans penis.¹⁸ This is due to excessive blood flow reaching the glans penis through arterialized collateral veins. Hypervascularity of the glans penis usually presents in the early postoperative period but may present late. The treatment consists of ligation of the collateral veins located between the arterialized segment of the deep dorsal and the glans penis. The intraoperative Doppler is helpful in identifying these arterialized collateral veins. The dorsal arteries should be spared to prevent ischemic damage to the glans. Alternatively, the inferior epigastric artery can be ligated proximal to the anastomosis if the original procedure was not effective in restoring potency.

RESULTS OF ARTERIAL RECONSTRUCTIVE SURGERY

In the past, objective criteria to select patients for penile vascular surgery have not been uniformly applied. In addition, the measures of success were often not standardized. Postoperative success in most surgical series has been based predominantly on subjective patient reporting. Few studies report objective postoperative data such as those from angiography or cavernosometry because patients are reluctant to have invasive studies postoperatively. Standardized questionnaires quantifying erectile function did not exist when the majority of the case series were reported.

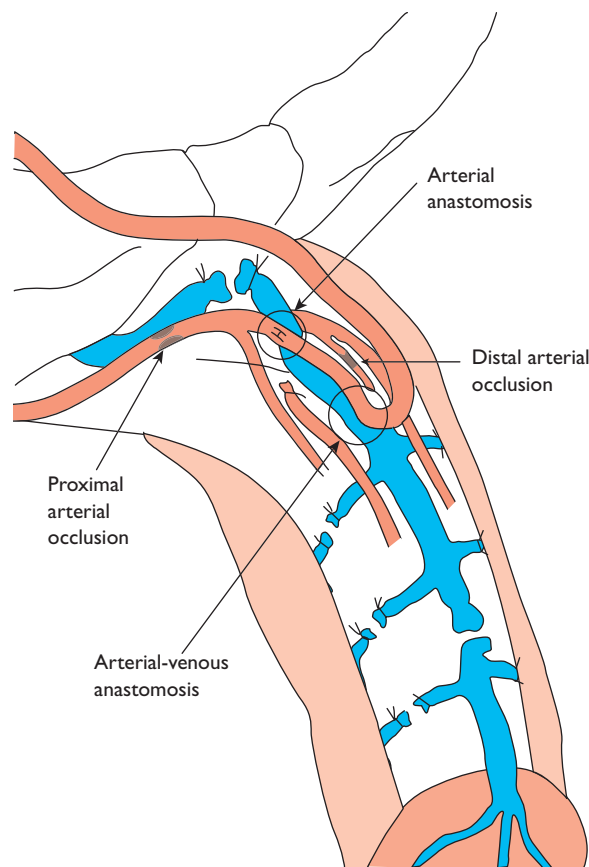


Figure 76.5 Schematic demonstrating the technique for simultaneous anastomosis of the inferior epigastric artery to the dorsal artery and vein of the penis. The advantage of this technique is that blood flow is maintained through the graft via the dorsal vein even during penile flaccidity, which would theoretically reduce the chance of graft thrombosis.

The most recent American Urological Association Best Practice Policy committee on ED sought to determine whether there is sufficient evidence at this time to state whether arterial vascular surgery is effective in any cohort of patients. The literature from 1966 to 2003 was reviewed to determine whether patients deemed most likely to favorably respond to arterial revascularization, those with traumatic segmental arterial injury without other predisposing risk factors, benefited from surgery. A total of 31 papers on penile vascular surgery were identified of which 27 were rejected after careful review due to failure to meet the specified criteria, leaving only four papers composed of 64 patients. Of these 64, nine had an anastomosis of the inferior epigastric artery to the dorsal penile artery (dorsal artery arterialization) and 55 had an anastomosis of the inferior epigastric artery to the dorsal penile vein (dorsal vein arterialization). Satisfactory outcomes, measured by objective criteria, ranged from

Table 76.2 Results of arterial reconstructive surgery in selected series

	<i>n</i>	Mean age (years)	Follow-up (months)	Success (%)	Procedure
McDougal and Jeffrey ¹⁹	8	55	>12	75	Dorsal artery
Hauri ¹⁷	50	—	—	78	Hauri procedure
Crespo et al ²⁰	257	—	60	77	Dorsal artery
Pearl and McGhee ²¹	10	—	60	60	Dorsal artery
Wagenknecht ²²	15	57	26	67	Dorsal vein
Konnak and Ohl ¹³	9	—	31	22	Cavernosal artery
Sohn et al ²³	74	44	15	55	Hauri procedure or dorsal vein
Löbelenz et al ²⁴	19	48	13	58	Hauri procedure or dorsal vein
Schramek et al ²⁵	35	42	27	77	Hauri procedure
Cookson et al ²⁶	12	38	24	67	Dorsal artery
Melman and Riccardi ²⁷	18	50	15	33	Dorsal artery
Janssen et al ²⁸	21	47	22	62	Dorsal artery or vein
Jarow and DeFranzo ²⁹	11	42	50	64	Dorsal artery or vein
DePalma ³⁰	12	—	33	27	Dorsal artery
Sarramon et al ³¹	114	—	17	48	Dorsal artery and vein
Manning et al ³²	62	48	41	34	Hauri procedure

54 to 91% of patients. The patient population of 64 was deemed too small to reach a definitive conclusion as to whether arterial reconstructive surgery is efficacious in this ideal candidate.

SUMMARY

The introduction in the early 1990s of surgical procedures to cure vasculogenic ED was greeted with a great deal of initial enthusiasm because of the limitations in other therapies available at that time. Vascular surgery is potentially a cure for ED while almost all other therapies are palliative at best. Unfortunately, the published long-term results of these procedures fall far short of our initial expectations. Numerous surgical techniques have been developed and modified and none appear to significantly improve outcome. The reported success rate for arterial surgery ranges from as low as 33% to as high as 78% depending upon the population treated, method employed, and length of follow-up (Table 76.2). The gaps in our understanding of erectile physiology and the flaws in our diagnostic evaluation may lead to a misdiagnosis and inappropriate application of these surgical therapies. The major causes of failure of penile revascularization are misdiagnosis, lack of adequate run-off in the vascular bed and corporeal fibrosis with associated disorders in veno-occlusion. It has learned which patients will not benefit from these procedures. They include any patient with end organ disease of the penis including the elderly, diabetics, and patients with severe ischemic vascular disease. Dynamic infusion cavernosometry and cavernosography is our least standardized test and

the lack of a gold standard method for the diagnosis of veno-occlusive dysfunction is a major handicap in ruling out this disorder in patients with known arterial occlusive disease. The best candidates for penile revascularization are young healthy patients with an identifiable segmental arterial occlusion such as patients with traumatic injuries. These patients are rare and represent only a small fraction of the patients seen in a standard clinical practice. Moreover, it is almost impossible to rule out concomitant nerve damage. Patients undergoing penile vascular surgery should be made aware of the potential risks, alternative therapies, and the investigational nature of these procedures.

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77 Reconstructive surgery for corporovenous occlusive dysfunction

Anthony J Bella, William O Brant, and Tom F Lue

Men often complain that the various modalities of treatment for erectile dysfunction (ED), while potentially effective, are not 'natural' in that they require assistance from a pill, injection, or device and do not allow for the same level of spontaneity previously enjoyed. Rather than symptom management, men desire a cure. With the exception of reversible endocrinopathies, no other available treatments address this fundamental desire. Since ED often has a vascular component, it stands to reason that practitioners have tried to develop surgical methods to re-establish penile vascular integrity. After a review of penile venous anatomy (Figure 77.1), we discuss venogenic causes of ED, evaluation, and surgical approaches.

Venous drainage from the three corpora originates in tiny venules leading from the peripheral sinusoids immediately beneath the tunica albuginea. These venules travel in the trabeculae between the tunica and the peripheral sinusoids to form the subtunical venular plexus before exiting as the emissary veins. Outside the tunica albuginea, venous drainage is as follows:

- (1) The skin and subcutaneous tissue drain through multiple superficial veins that run subcutaneously and unite near the root of the penis to form a single (or paired) superficial dorsal vein, which in turn drains into the saphenous veins. Occasionally, the superficial dorsal vein may also drain a portion of the corpora cavernosa.
- (2) In the pendulous penis, emissary veins from the corpus cavernosum and spongiosum drain dorsally to the deep dorsal, laterally to the circumflex, and ventrally to the periurethral veins. Beginning at the coronal sulcus, the prominent deep dorsal vein is the main venous drainage of the glans penis, corpus spongiosum, and distal two-thirds of the corpora cavernosa. Usually, a single vein, but sometimes more than one deep dorsal vein, runs upward behind the symphysis pubis to join the periprostatic venous plexus.
- (3) Emissary veins from the infrapubic penis drain the proximal corpora cavernosa and join to form cavernous and crural veins. These veins join the periurethral veins from the urethral bulb to form the internal pudendal veins.

EVALUATION OF PENILE VASCULAR PHYSIOLOGY AND ANATOMY

Very few patients require formal evaluation of penile physiology or anatomy prior to first-line treatments. There are, however, several indications for formal testing. The one that is most germane to this chapter is that testing is required when it will change disease management, especially in regard to planned reconstructive procedures to correct veno-occlusive dysfunction. Other indications include young patients with primary ED, patients who have undergone significant trauma to the pelvis or perineum, patients with Peyronie's disease, and patients involved in litigation or other proceedings requiring specific evaluation. In patients with small-vessel disease, eventually the connective tissues of the corpora cavernosa undergo histopathologic changes that compromise the normal compliance and veno-occlusive processes. If there is diffuse disease and lack of tissue compliance, surgical repair of either inflow or outflow will not be successful. Many patients who present with ED are older, use tobacco, and have systemic vascular disease or other chronic conditions resulting in small-vessel disease. These patients do not require formal penile vascular evaluation, since they are not candidates for vascular reconstructive surgery.

The first procedure we perform in clinic on an appropriate patient is a combined intracavernous injection (ICI) and stimulation test. This consists of injection of one to three vasodilatory agents followed by self-genital stimulation and assessment of the resultant erection.¹ We typically inject 9 mg of papavarine and 15 µg of phentolamine, with or without 3 µg of prostaglandin E1. For the most part, this test bypasses neurologic influences and assesses the vascular status directly, although patients with severe psychogenic ED may not respond fully. The pharmacologic test, especially combined with self-genital stimulation or audio-visual sexual stimulation^{2,3} yields important information regarding penile vascular status. A positive response (normal erectile rigidity of sustained duration) presumably excludes significant venous or arterial pathology. More contemporary studies suggest normal response

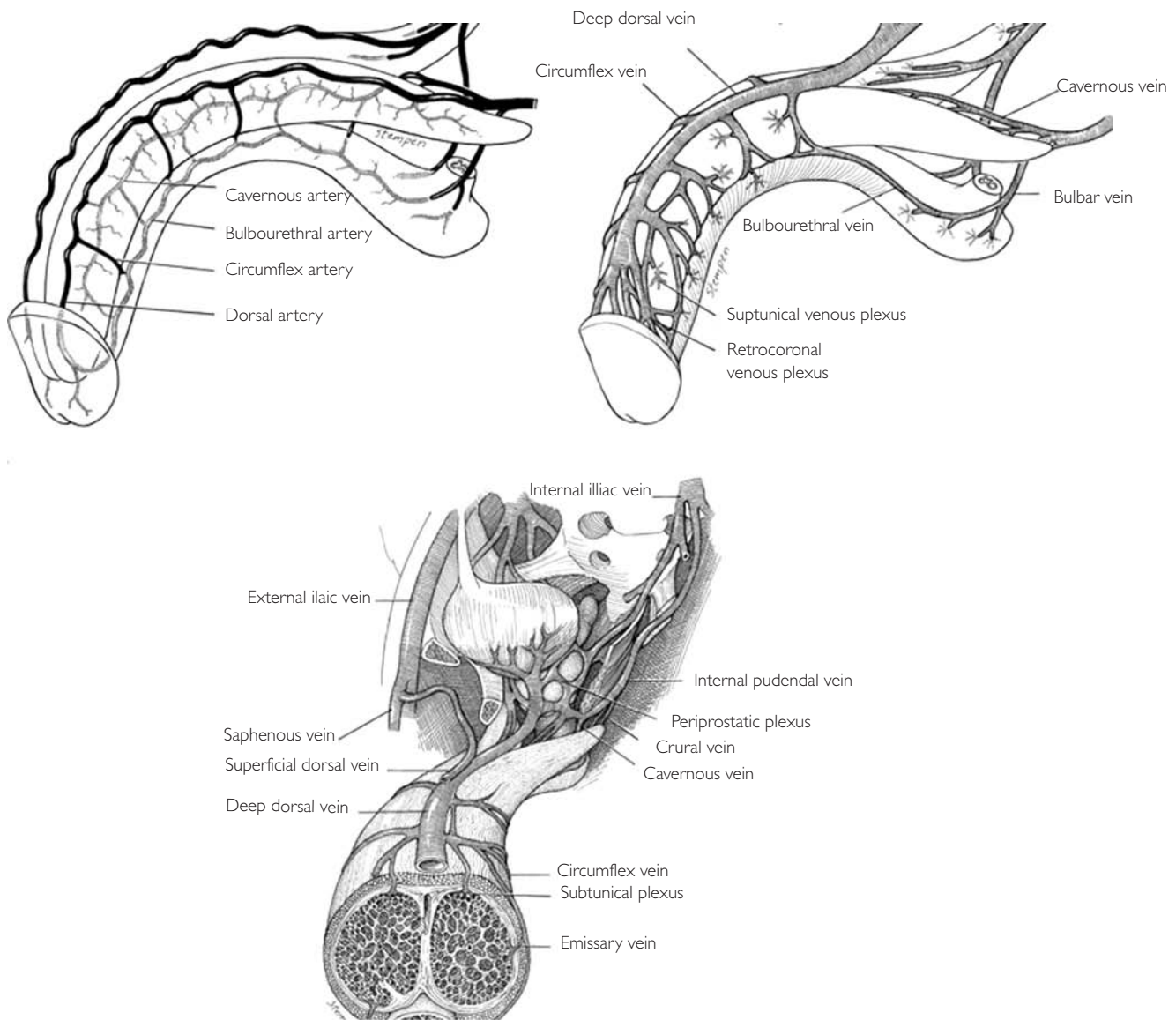


Figure 77.1 Penile vascular anatomy. From reference 1, with permission.

rules out the possibility of venous leakage, although some patients (about 20%) with arterial insufficiency will also achieve a rigid erection.⁴ Generally, a normal office pharmacotest with ICI and stimulation suggests that neurogenic, psychogenic, or hormonal factors may be primarily responsible for ED, although pharmacotesting is unable to distinguish among them. Nonetheless, further evaluation for veno-occlusive dysfunction is rendered unnecessary. Correlation with both Doppler ultrasound and cavernosometry/cavernosography confirms that a positive pharmacotest is consistent with normal veno-occlusion (flow to maintain erection values of 0.5–3 ml/min; see below for further detail) but may occur with borderline arterial function, when

normal is defined as a peak systolic velocity (PSV) greater than 35 cm/s and borderline as 25–35 cm/s.⁵ Office pharmacotesting, despite its lack of specificity, is cost effective and clinically helpful.

An abnormal pharmacologic test result suggests penile vascular disease (arterial, venous, or mixed vascular) and warrants further evaluation, although it may not always be indicative.^{6–8} To investigate abnormal responses to the combined pharmacologic/stimulation test, we perform color duplex ultrasound of the penile arteries (CDU). This test combines pharmacologic testing with the ability to visualize and measure arterial blood flow. ICI of a vasodilator produces arterial and arteriolar dilatation, cavernous smooth muscle

relaxation, and a drop in the peripheral vascular resistance within the penis. Together, these changes cause an increase in penile arterial inflow. This increase is manifested sonographically as detectable increases in cavernous arterial diameter and blood flow velocity. The timing of ultrasonography in relation to the state of erection is important for interpretation of the results. Schwartz et al⁹ correlated changes in Doppler waveforms with hemodynamic changes in corporeal pressure during progression to full erection. After vasoactive injection, the filling phase (5 minutes) is characterized by low sinusoidal resistance and a waveform demonstrating high forward flow during both systole and diastole. As intracavernous pressure increases, diastolic velocities decrease. With full erection, the systolic waveforms sharply peak and may be slightly less than during full tumescence. In rigid erection, diastolic flow will be zero, cavernous pressure may transiently exceed systemic diastolic blood pressure, and reversal of diastolic flow occurs in the cavernous artery. With CDU, reversal of diastolic flow is associated with a dramatic color shift from red to blue in the cavernous artery. The absence of these expected Doppler spectral waveform changes allows the experienced sonographer to document significant penile hemodynamic pathology.

Parameters used to infer the adequacy of penile circulation include PSV, end-diastolic arterial velocity (EDV), systolic rise time measured in milliseconds from the start of systolic velocity to the maximum value, and cavernous artery acceleration, which is calculated by dividing PSV by systolic rise time.^{10,11} Flow velocities should be measured 5–10 minutes after injection; a delay in response is typical in both the hypertensive and the anxious patient.

Total blood flow is a function of both arterial diameter and blood flow velocity. By evaluating a large number of patients with non-arteriogenic causes of impotence (e.g. neurogenic or psychogenic), Lue et al established that the PSV within the cavernous arteries should exceed 25 cm/s within 5 minutes of ICI.^{12,13} These findings have been confirmed by others.^{14–18} In the University of California San Francisco series, normal subjects had mean PSVs of 34.8 cm/s, while other studies reported normal volunteer mean PSVs of 40 cm/s.¹⁹

Abnormalities found on duplex ultrasonographic testing may lead to suspicion of either arteriogenic or venogenic etiologies of ED. A poor PSV despite a typically adequate dose of an intracavernosal vasodilator combined with self-stimulation should lead to further evaluation of an arterial cause. A persistently elevated EDV and/or transient rigidity after self-stimulation

despite appropriate arterial response (>25 cm/s) should lead to further evaluation of a venous problem. Quam et al found EDVs ranging between 0 and 24 cm/s after intracavernous administration of papaverine (60 mg). Among patients with PSVs greater than 25 cm/s, venous leakage on cavernosometry was predicted with a sensitivity of 90% and specificity of 56% when EDV was greater than 5 cm/s.¹⁷

For evaluation of patients in whom a venous etiology is suspected, the most commonly performed test is pharmacologic cavernosometry and cavernosography. The principle of cavernosometry is that infusion of saline after pharmacologic smooth muscle relaxation should lead to sustained cavernosal pressure equal to mean systolic blood pressure and that this pressure should remain stable after infusion ceases. A standard definition of normal is that, under the conditions of complete smooth muscle relaxation no more than 5 ml/min infusion is necessary to maintain an erection with intracavernous pressure of 100 mmHg, and if infusion is stopped at an intracavernous pressure of 150 mmHg, there should be less than a 45 mmHg drop over 30 seconds. Only if cavernosometry reveals abnormalities does one proceed to cavernosography. This involves infusion of 50% diluted contrast medium into the corpora cavernosa while the corporal smooth muscles are maximally relaxed. With venous pathology, contrast may be seen leaking to the glans, corpus spongiosum, superficial and deep dorsal veins, cavernous, and crural veins (Figure 77.2). In the majority of patients, more than one site is visualized.^{20–22} Since venous leakage is the consequence of diffuse corporeal smooth muscle pathology rather than discrete diseased areas in the majority of older men with secondary erectile dysfunction,²³ cavernosometry/graphy should be reserved for young men with primary ED or a history of trauma, since they may be candidates for venous surgery.

VENOUS LIGATION SURGERY

The complexity of the venous drainage of the penis may be a primary reason explaining the lack of long-term success of venous ligation procedures. In the majority of patients, multiple venous leak sites can be visualized. Common leak sites include the superficial and deep dorsal vein, crural veins, corpus spongiosum, and glans penis. Various surgical procedures have been described aimed at correcting the radiographic finding of venous leakage. Although multiple drainage sites



Figure 77.2 Cavernosogram showing leakage into the deep venous system.

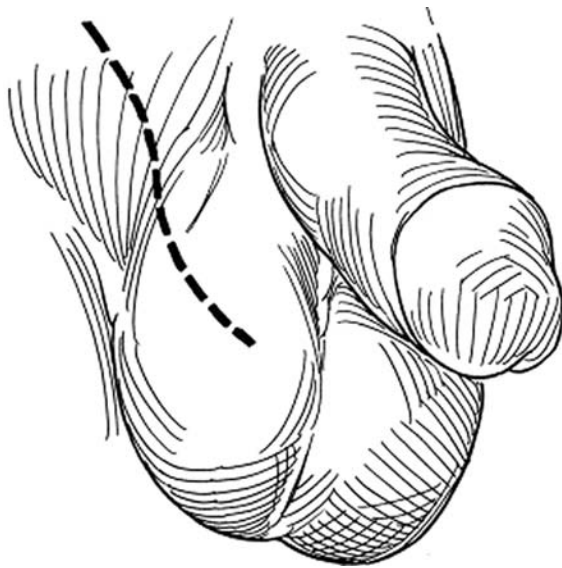


Figure 77.3 Inguinoscrotal incision. From reference 1, with permission.

and communications may be visualized on cavernosography, the deep dorsal vein is the main venous drainage of the corpora cavernosa and is the most common site for ligation procedures.

A variety of surgical techniques have been developed to treat patients with venogenic ED. We prefer deep dorsal vein resection and crural ligation. The procedure is performed through an inguinoscrotal incision (Figure 77.3). After releasing the suspensory ligaments, the penis is detached from the pubic bone. The deep dorsal vein is identified and ligated proximally and distally. Careful dissection of the cavernous and

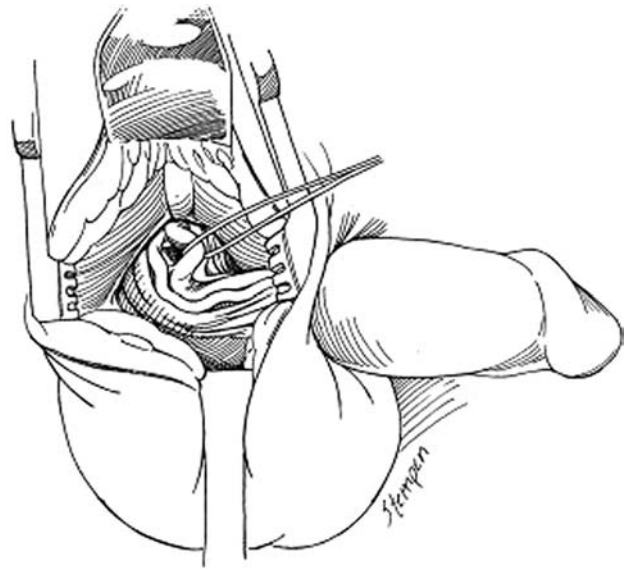


Figure 77.4 Identification of deep dorsal vein. From reference 1, with permission.



Figure 77.5 Intraoperative view of the deep dorsal vein.

dorsal arteries and the dorsal and cavernous nerves is then performed at the hilum of the penis; this is considerably aided with the use of loupe magnification (Figures 77.4 and 77.5). Once the entrance of the cavernous arteries is identified and the dorsal neurovascular bundle lifted from the tunica, a urethral catheter is inserted and a 0.5 cm segment of the crura isolated. Two umbilical tapes are then looped around each crus and ligated (Figures 77.6 and 77.7). It is extremely important to exclude the neurovascular bundle and the cavernous arteries from the ligated areas. The penis is then reattached to the periosteum of the pubis with

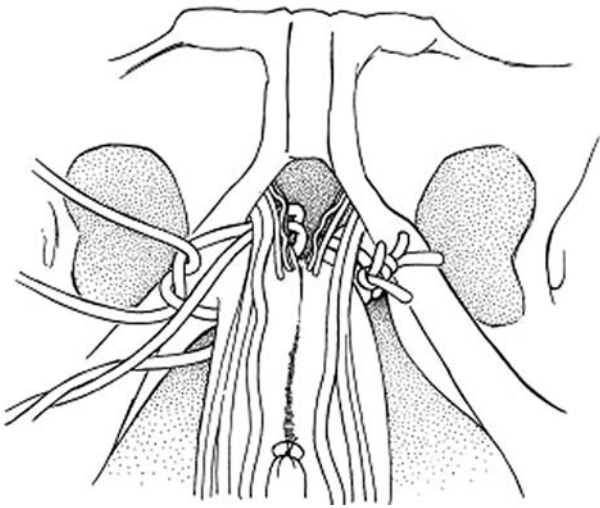


Figure 77.6 Crural ligation. From reference 1, with permission.

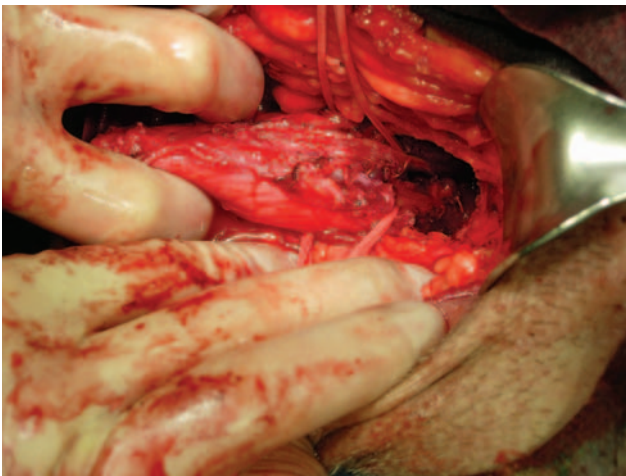


Figure 77.7 Intraoperative view of isolation of crura, excluding the neurovascular bundle.

non-absorbable sutures and the tissue closed in layers to prevent penile shortening. In the uncommon occurrence of a unilateral leak, the involved crus may be ligated with good results (Figures 77.8–77.10).

In rare cases, more diffuse venous leakage may be successfully addressed surgically. One of our patients was a young man who developed leakage from the dorsal aspect of the tunica albuginea after overexuberant play with a commercial vacuum erectile device. Since his leakage was secondary to trauma rather than an underlying medical condition, we offered surgical exploration and found multiple discrete venous leakage sites after mobilization of the dorsal neurovascular bundle (Figure 77.11). Each of these was ligated separately and the patient had a good outcome at



Figure 77.8 Patient after repair of industrial accident.



Figure 77.9 Cavernosogram of patient in Figure 77.8, showing unilateral right crural leakage.

12-month follow-up. However, this scenario is quite rare and we do not routinely repair diffuse leakages, as they are overwhelmingly prone to failure.

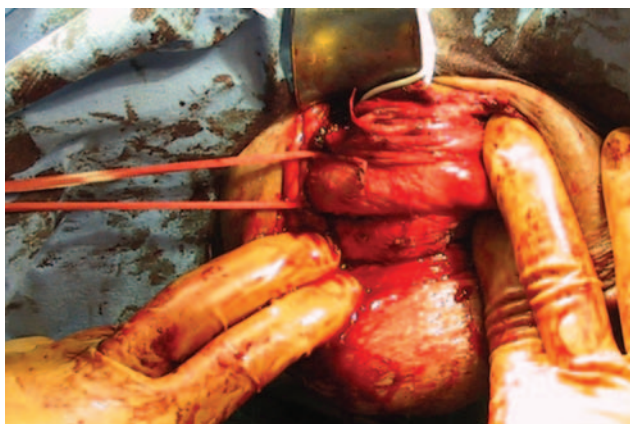


Figure 77.10 Unilateral crural ligation of patient in Figure 77.8.



Figure 77.11 Venous leak from injury. Scalp needle is used to infuse methylene blue to demonstrate leakage sites.

RESULTS OF PENILE VENOUS SURGERY

Despite the promising early results of penile venous surgery, longer-term results have been disappointing. Although several authors have reported short-term success rates of up to 70% in selected patients, longer-term follow-up shows a significant decline in functional improvement.^{24–29} Similarly, some authors have suggested that results of penile venous surgery should not include patients who have been followed for less than 12 months due to the high late failure rate of the procedure.^{30,31} Development of venous collaterals and persistent venous leakage appear to be contributing factors in many patients who fail to improve following venous surgery. Factors which may predict a poor prognosis include increasing patient age, duration of impotence,

the presence of multiple leak sites, and concomitant arteriogenic insufficiency.^{24,32,33} We recently reported³⁴ on 11 cases of crural ligation performed on patients with congenital crural venous leak seen on cavernosography. Of these patients, two reported no change in erection and did not desire further work-up. Four of the remaining nine men required oral phosphodiesterase-5 inhibitors intermittently. Of these four, two had progressive decline in erectile function, prompting repeat cavernosograms. These both showed persistent leakage, although not to the degree seen preoperatively, and both had successful repeat crural ligation surgery. Therefore, seven out of 13 surgeries (counting the repeated cases twice) led to a great improvement over the pretreatment state, while five of the 13 surgeries resulted in potency without use of pharmacologic assistance. In this series, the average age was 28 and all patients had primary ED (i.e. no history of normal erections). Therefore, this represents the most highly selected patient population in whom surgery should yield the best results.

CONCLUSIONS

The vast majority of patients presenting with complaints of ED do not require specialized, and possibly invasive, testing to determine whether there is a vascular etiology of their disease. Few of these patients will have a discrete venous lesion that is amenable to surgical repair. Overall, the results of vascular approaches to erectile disease are disappointing, especially when one examines long-term durability of venous ligation approaches to venogenic causes.²⁹ In large part, this results from loose surgical selection criteria. Patients with diffuse involvement of penile vasculature and compromised sinusoidal compliance are poor candidates for vascular penile surgery. However, there is certainly a role for venous surgery in highly selected patients, such as young men without substantial vascular comorbidities who have sustained trauma or have congenital anomalies. Even in these patients, outcomes are less than ideal and there are risks including the need for further procedures that may lead to renewed ED, penile hypoesthesia, penile shortening, and skin breakdown. Patients need to be aware of such risks, as well as alternative therapies, prior to pursuing these approaches.

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78 Penile prosthesis implantation

Matthew K Tollefson and Ajay Nehra

BACKGROUND

The introduction of effective oral medications has revolutionized treatment options for erectile dysfunction (ED). These medications have increased the visibility of the disorder and have increased the acceptance of ED in the general public. For most men, systemic oral therapy with a phosphodiesterase inhibitor, such as sildenafil, vardenafil, or tadalafil, will be sufficient as these medications have demonstrated long-term safety^{1,2} and efficacy.^{3,4} For men in whom systemic therapy is unsuccessful or contraindicated due to underlying medical conditions, alternative therapies exist. Intracorporeal injection therapy, intra-urethral prostaglandin, and vacuum erection devices all provide reasonable options for many men with ED. However, placement of a penile prosthesis remains the sole surgical therapeutic option for many patients and it is a successful procedure in almost every patient population.

The term prosthesis is defined as an artificial extension that replaces a missing or defective body part. The first penile prostheses were used in the 16th century. These wooden devices were largely used for urethral substitution in men who suffered severe war-related injuries and originally were never intended for sexual function. The first attempts to reproduce penile rigidity were developed in the 1930s and 1940s. These procedures involved placement of rib cartilage in the phallus in a manner similar to the os penis of some animals.⁵ These early attempts at increasing penile rigidity failed, in large part, due to the reabsorption of the implanted material as well as a lack of simulating the flaccid phallus. The first synthetic materials placed subcutaneously were used in the early 1950s,⁶ with the first intracorporeal prostheses placed a few years later.^{7,8}

The modern era of urologic prosthetics was born following advances in silicone and acrylic technology in the 1950s and 1960s, largely a byproduct of the aerospace industry. These improved synthetic polymers allowed for more reliable semirigid devices and allowed for the development of inflatable prostheses. Scott et al⁹ reported the first successful placement of an inflatable prosthesis into the corpora cavernosa. The Small-Carrion prosthesis was introduced in

1975,¹⁰ served as a prototype for the design of many subsequent semirigid devices, and has been the most widely implanted semirigid rod prosthesis. In 1983, the Mentor Corporation introduced a new polyurethane-based inflatable prosthesis which improved longevity and decreased mechanical failures of inflatable devices.¹¹

The success of these early devices led to increased awareness of this common problem. This stimulated research into the physiology of the male erection, and subsequently penile injection therapy,¹² oral phosphodiesterase inhibitors,¹³ and vacuum erection devices¹⁴ were popularized. All of these therapies provide reasonable treatment options for most patients (greater than 95%). Recently penile implants have played a more secondary role in the management of ED. However, due to the increased awareness of the problem and the acceptance of treatment options, there has been a resurgence in the numbers of penile implants placed.¹⁵ Penile prostheses remain important options for several patient populations since oral phosphodiesterase inhibitors are contraindicated in patients taking oral nitrates. Additionally, patients with diabetes mellitus and patients following pelvic surgery may have less success with oral and intracavernosal therapy. Finally, in men with Peyronie's disease, in whom penile curvature in conjunction with changes in erections may make intercourse impossible, a penile implant may be ideally suited.¹⁶

AVAILABLE DEVICES

Penile prostheses fall into two broad categories: semirigid and inflatable devices (Table 78.1). Semirigid devices are an excellent option for men who have limited dexterity, providing an erection with good rigidity. Semirigid penile prostheses have the advantage of ease in placement by the surgeon, easier use by the patient, less chance of mechanical malfunction, and lower cost. The disadvantages include less concealability, no change in girth, a poor simulation of the flaccid penis, and a higher rate of prosthesis erosion.^{17,18}

Semirigid penile prostheses are available in two varieties, mechanical and malleable. Malleable devices are

Table 78.1 Advantages and disadvantages of semirigid and inflatable penile protheses

Type	Advantages	Disadvantages
Semirigid	Ease of use in men with limited dexterity Less expensive Shorter surgical procedure Less likely to have mechanical failure	Remains firm when not erect More difficult to conceal Higher risk of erosion, especially in spinal cord injured patients Higher risk with repeated cystoscopy
Inflatable	More natural appearing flaccid penis More physiologic erection Easier to conceal	Requires some manual dexterity to pump Possibility of mechanical breakdown Requires pump and reservoir placement

Table 78.2 Current commercially available penile prosthesis

Type	Prosthesis	Vendor
<i>Semirigid</i>		
Malleable	650 600M	AMS AMS
	Accuform	Coloplast A/S
Mechanical	Dura II	AMS
<i>Inflatable</i>		
Two-piece	Ambicor	AMS
Three-piece	Titan	Coloplast A/S
	Alpha I	Coloplast A/S
	700 CX	AMS
	700 Ultrex	AMS
	700 CXR	AMS

AMS, American Medical Systems, Minnetonka, Minnesota.
Coloplast A/S, Humlebaek, Denmark (formerly produced by Mentor Corporation).

generally composed of a woven metallic core enclosed within a solid silicone body. Recent modifications to the design have allowed greater flexibility with less memory. Malleable prostheses are produced by both AMS (600M and 650; American Medical Systems, Minnetonka, MN) and Coloplast (Accuform; Coloplast A/S, Humlebaek, Denmark). Mechanical semirigid prostheses are composed of articulating segments of high molecular-weight polyethylene. These articulating segments are coated with a polytetrafluoroethylene (Teflon®) sleeve within a thin membrane of silicone containing a core of reinforced cable attached to distal and proximal spring systems. The spring systems apply enough tension to maintain the prosthesis in either a flexed or a straight position. The only currently available mechanical device is the Dura II, produced by AMS (Table 78.2).

Inflatable penile prostheses consist of either two- or three-piece devices. The standard three-piece penile prosthesis includes a scrotal pump with deflation

mechanism and an abdominal fluid reservoir, whereas the two-piece prosthesis combines the reservoir and pump in a single scrotal device. Historically, AMS produced a one-piece inflatable prosthesis, the Dynaflex; however, it was discontinued due to difficulty with patient use and small reservoir size. The only currently approved two-piece prosthesis is the AMS Ambicor. The advantages of the two-piece device include easier placement (no suprapubic reservoir) and ease of inflation and deflation. Disadvantages include the difficulty in reproducing the flaccid penis and a perceived smaller erect penis secondary to a decreased volume of fluid transferred from the scrotum pump/reservoir.

Both AMS and Coloplast produce several three-piece prostheses as illustrated in Table 78.2. Of the currently available devices, the three-piece penile implant most closely imitates the flaccid and erect penis allowing a patient to control the duration of his erections. These devices promote spontaneity, which is often a patient complaint with oral medications, intracavernosal pharmacotherapy, and vacuum erection devices. The three-piece penile implant contains a large volume reservoir which allows for larger fluid transfers and a more physiologic erection. Upon deflation, this prosthesis is nearly undetectable, and when inflated, it appears similar to the erect penis.

In summary, selection of the appropriate prosthesis is dependent upon patient preference, cost, and surgeon clinical judgment. To make a more informed decision, patients should be aware of the various options and, when available, given the opportunity to see and feel a prosthesis in the outpatient setting.

PREOPERATIVE COUNSELING

Prior to any prosthesis implantation, preoperative patient and partner counseling is integral. The primary objective of preoperative counseling is to provide the

Table 78.3 Advantages and disadvantages of various surgical approaches

Incision	Advantages	Disadvantages
<i>Penoscrotal</i>	Excellent corporeal exposure to crura Excellent exposure of urethra Direct fixation of scrotal pump	Blind placement of suprapubic reservoir
<i>Infrapubic</i>	Placement of reservoir under direct vision No separate incision for reservoir	Limited corporeal exposure Difficult placement of scrotal pump Difficulty in identifying the urethra Possible damage to dorsal nerves of penis
<i>Ventral penile and subcoronal</i>	Smaller corporotomy required May be performed with local anesthesia	Limited visualization when dilating corpora Inability to place reservoir or pump through same incision

patient with realistic expectations since dissatisfaction may be secondary to undue expectations or a failure of adequate preoperative counseling. Patients should be informed that the procedure may result in an erect penis smaller than their original erection. Sensitivity, ejaculatory abilities, and sexual drives are usually unchanged but may not be similar to what they experienced years ago. They should also understand that placement of the prosthesis is a permanent choice. If the device is removed, they are not likely to respond to other alternative treatments such as oral medications, injection therapy, or vacuum devices due to the development of corporeal fibrosis. Patients should be aware of the potential complications of the operation including infection, mechanical failure, and erosion, and understand that many of these complications may require explantation of the prosthesis.

TECHNIQUES

When in the operating room, the patient is typically positioned in the supine position. A Foley catheter is recommended for bladder drainage and potentially to minimize the risk of injury to the bladder during reservoir placement and may help in identifying the urethra when using the penoscrotal approach. While infrapubic and penoscrotal approaches are the most common surgical incisions, our approach has been to use a penoscrotal incision in most cases, with exceptions for patients presenting for device malfunction/revision procedures following a primary infrapubic approach. Table 78.3 describes the advantages and disadvantages of the available surgical incisions for prosthesis placement. Surgical instruments for placement of the cylinders include tools for corporeal dilatation of the corporeal space such as Hagar, Brooks, or Dilamazeinsert dilators (Figures 78.1 and 78.2), rubber-shodded clamps for temporary clamping of the device,



Figure 78.1 Dilamazeinsert dilator, note markings on side showing depth of insertion.

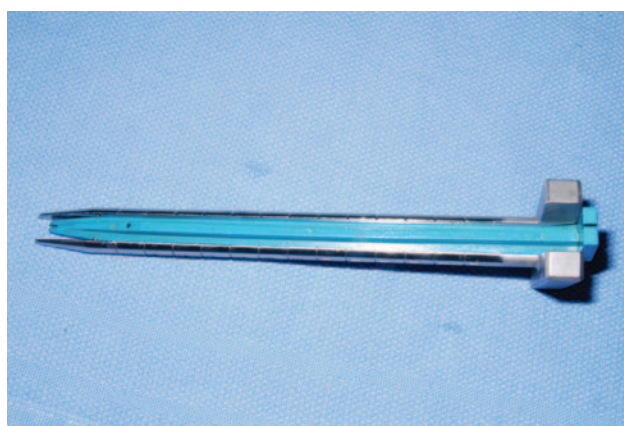


Figure 78.2 Dilamazeinsert dilator with plastic insert in place showing degree of dilation.

and a Furlow cylinder introducer (Figure 78.3). Other surgical instruments may be necessary for revision surgery or in cases of severe corporeal fibrosis.¹⁹



Figure 78.3 Furlow cylinder introducer.

Semirigid prostheses

Placement of semirigid penile prostheses can generally be performed in an ambulatory surgery center on an outpatient basis. They may be inserted with a subcoronal (Figure 78.4A), ventral penile, penoscrotal, or infrapubic approach under regional or general anesthesia. Dilatation of the corpora and closure of the corporotomy incision is performed similarly to the inflatable prosthesis described below. Care should be taken handling the prosthesis as rough manipulation with surgical instruments or bending to non-physiologic angles may

damage the prosthesis and reduce longevity. Technical differences make the procedure much easier than the placement of an inflatable prosthesis. For example, placing a suture inadvertently through the device is not the catastrophic event that it is with inflatable prostheses.

Inflatable prostheses

Insertion of an inflatable penile prosthesis, is performed with a 3–4 cm transverse incision two finger breadths below the penoscrotal junction to allow optimal access to the proximal penile crura (Figure 78.4B). In cases with extensive corporeal fibrosis or difficult distal dissection, this incision may be extended along the penile shaft. This incision allows access to the entire length of each corpus cavernosum.

The incision is then carried through dartos fascia until the urethra and each corporeal body are visualized (Figure 78.5). A 3 cm full-thickness corporotomy incision is then made longitudinally approximately 1–1.5 cm from the lateral margin of the corpus spongiosum (Figure 78.6). Sutures of 2-0 polyglactin 910 (Vicryl) are then placed at the proximal, distal, and midportion of the corporotomy (Figure 78.7). The proximal suture is left attached to the needle for subsequent corporotomy closure. In cases of severe corporeal fibrosis, the corporotomy incision may be extended the length of the corporeal body (Figure 78.8). In these

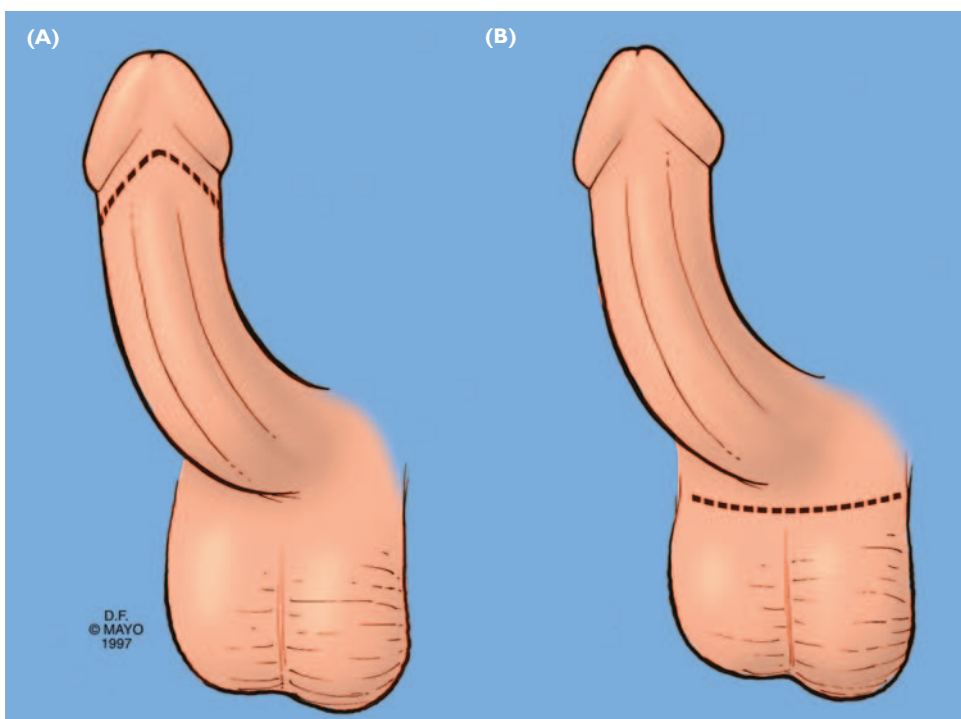


Figure 78.4 Subcoronal incision (A) and transverse penoscrotal incision (B)

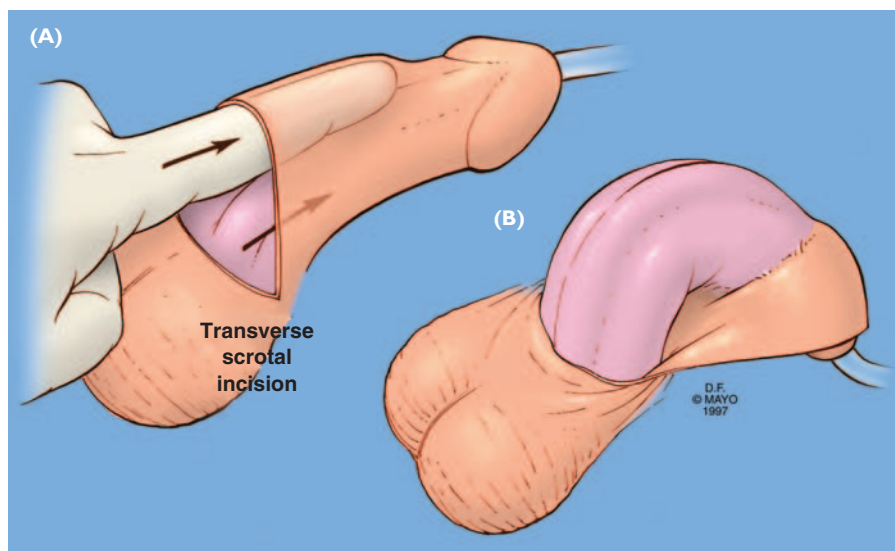


Figure 78.5 Exposure of the corporal bodies through a transverse penoscrotal incision.

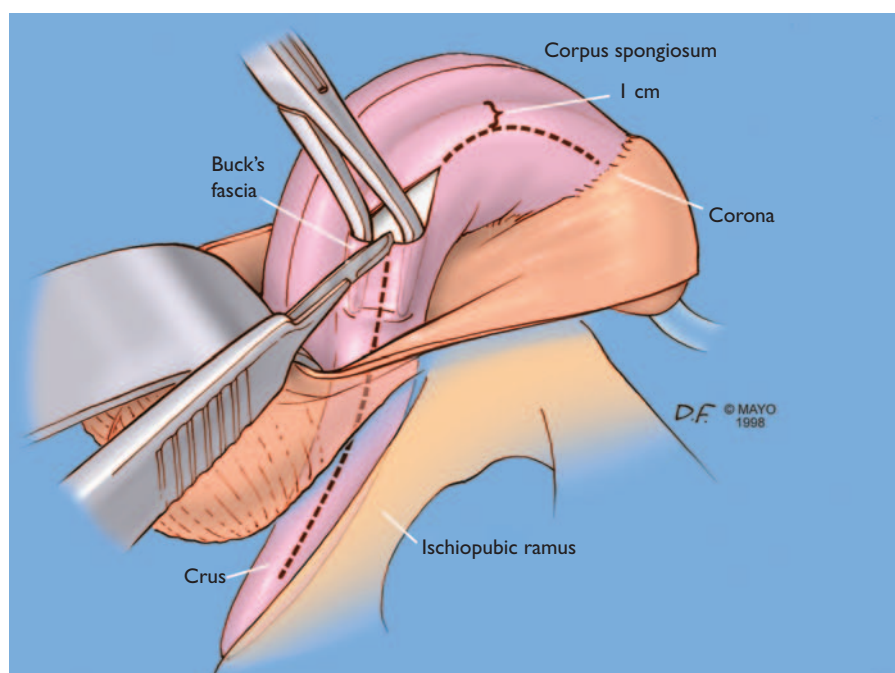


Figure 78.6 Corporotomy incision 1 cm lateral to corpus spongiosum. In cases of severe corporeal fibrosis, this incision may be extended from the crus to the corona (dotted line).

cases, it may be necessary to excise a portion of the fibrosed corpora in order to insert the 22 Fr prosthesis (Figure 78.9).

Proximal corporeal dilatation is then performed depending upon surgeon preference with a Dilamaze-insert dilator (Figure 78.10) or Hagar/Brooks dilators with attention being directed to dilate on the lateral aspect of the corpora since urethral injury/perforation is rare, but is possible if the corpus is dilated too medially. Dilatation continues until the proximal corpus is completely dilated and the ischial tuberosity

appreciated. Dilatation should be easy to perform, and difficulty should raise concern regarding an improper plane of dissection, crossover to the contralateral corporeal body, or urethral injury.

Distal dilatation is then performed with the Dilamazeinsert to approximately 16 mm. Again, emphasis must be made on dilating the lateral aspect of the corporeal body as distal urethral perforation may occur. Palpation of the glans penis confirms the distal extent of the dilatation (Figure 78.11). This entire procedure is then repeated on the contralateral side.

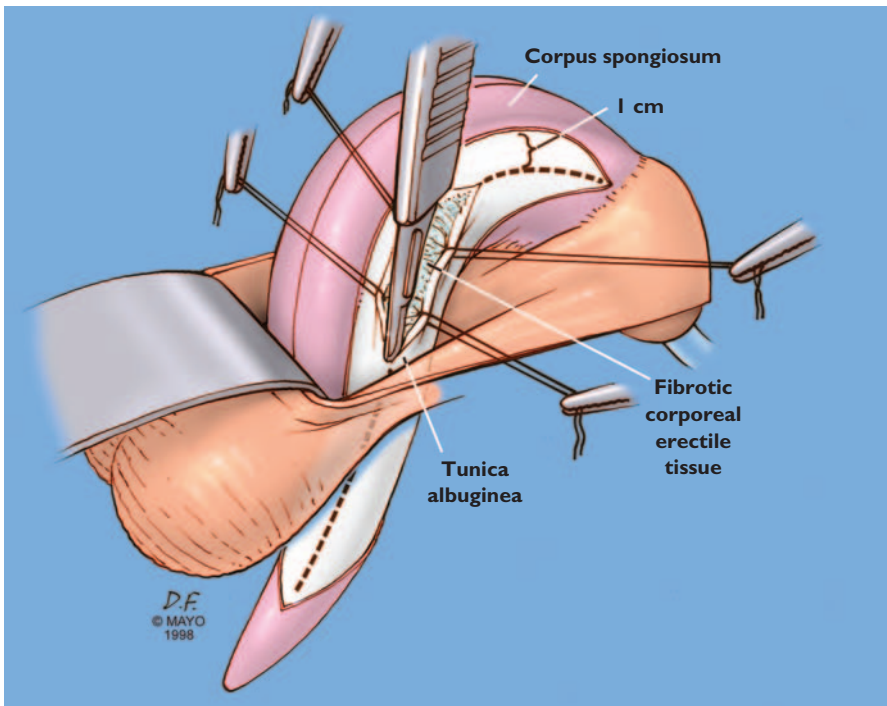


Figure 78.7 Stay sutures to delineate edges of corporeal incision in case with mild corporeal fibrosis.

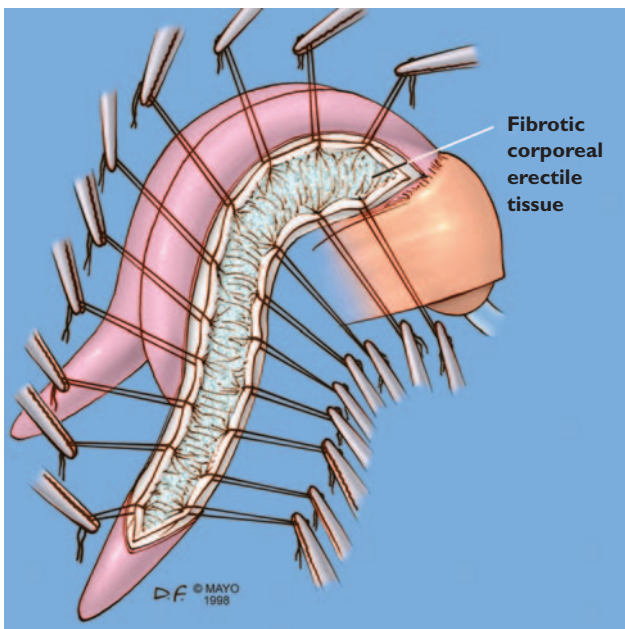


Figure 78.8 Stay sutures in case with severe corporeal fibrosis requiring extended corporotomy incision.

Using one of the lateral stay sutures, a measurement is made both proximally and distally. The lengths are added to determine the ideal cylinder length with no length discrepancy between sides. The appropriate reservoir size and cylinder length are prepared at the

back table. This involves removing air from reservoir, cylinders, and the pump as well as clamping the tubing with rubber-shod clamps.

Rear tip extenders may be an adjunct to obtain full measured penile length and when used are incorporated into the cylinders. Ideally, it is recommended that the use of rear tip extenders should be minimized to maximize girth and rigidity with the ideal prosthesis length. This usually is the result of proximal corporotomy allowing placement of full length cylinders while minimizing use of rear tip extenders. The proximal portion of the cylinder is inserted into the proximal corpus cavernosum. Pushing gently on the exit tubing hub may be the easiest way to advance the cylinder to the most proximal portion of the corpora. This procedure is then repeated on the contralateral side.

Following placement of the proximal portion of the cylinder, attention is turned to the insertion of the distal portion of the cylinder. A Furlow cylinder introducer is used to place a straight needle through the distal corporeal tip and the mid-glans. The needle is attached to a suture that is threaded through the cylinder tip. The suture is then used to pull the cylinder into the distal corpus cavernosum. Once the cylinder has been placed, it should lie flatly within the corpus cavernosum to prevent kinking or malfunction of the device.

The corporotomy incision is then closed by using the previously placed 2-0 Vicryl suture. We close the corporotomy in a running fashion (Figure 78.12).

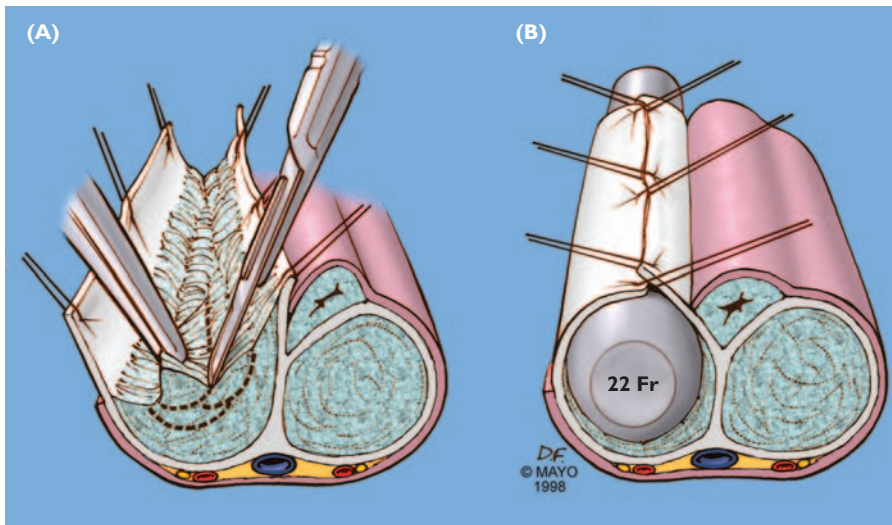


Figure 78.9 Excision of fibrosed corpora cavernosa to allow placement of 22 Fr prosthesis.

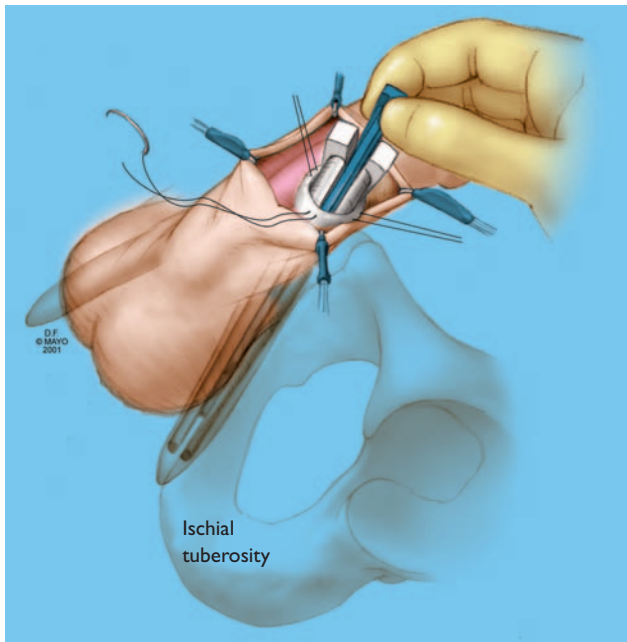


Figure 78.10 Proximal corporeal dilation with Dilamazeinsert dilator. Note attention to lateral emphasis of dilation.

In cases of severe fibrosis, we close the corporotomy in a vertical mattress fashion, tying the sutures in a double-stranded fashion to increase the tensile strength of the repair. A previously placed 14 Fr silicone Foley catheter is then checked to ensure adequate drainage of the bladder prior to placement of the reservoir.

The surgeon's index finger is then inserted into the incision and bluntly advanced to the external ring. Depending on inguinal scarring, prior pelvic/abdominal surgeries and patient preference the reservoir can be

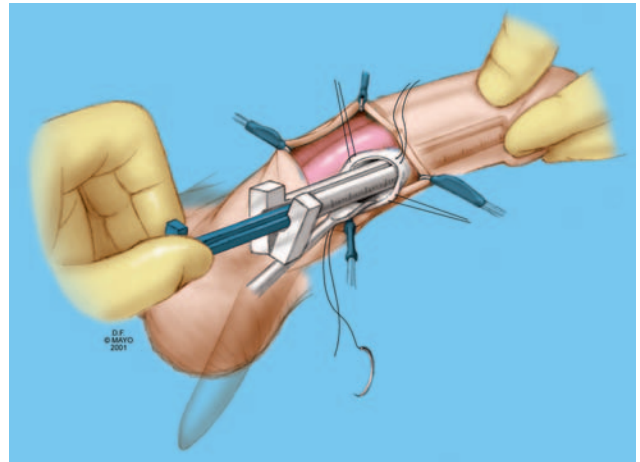


Figure 78.11 Distal corporeal dilation with Dilamazeinsert dilator. Again note emphasis of lateral placement of dilation.

placed on either the right or left side peri-vesically. The transversalis fascia is then bluntly perforated at a point just above the pubic tubercle. A space large enough to admit the tip of the index finger can be created in this manner. Prior surgery, such as hernia repair, varicocele ligation, and radical prostatectomy may make this perforation more challenging. In cases of severe scarring due to previous surgery, a midline incision may be useful to perforate the linea alba (Figure 78.13). The reservoir may then be placed anterior to the bladder in the retropubic space (Figure 78.14). Through this perforation, a cavity is created in the retropubic space using blunt dissection with the surgeon's index finger. The empty reservoir is then placed along the surgeon's index finger and advanced into the retropubic space. The

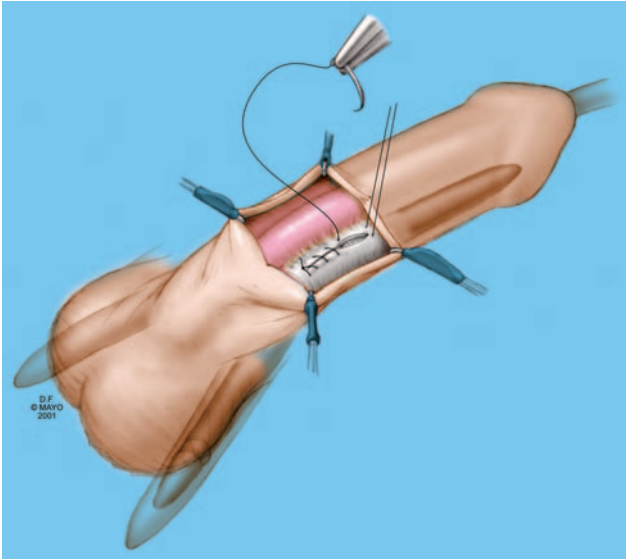


Figure 78.12 Closure of corporotomy incision with running suture.

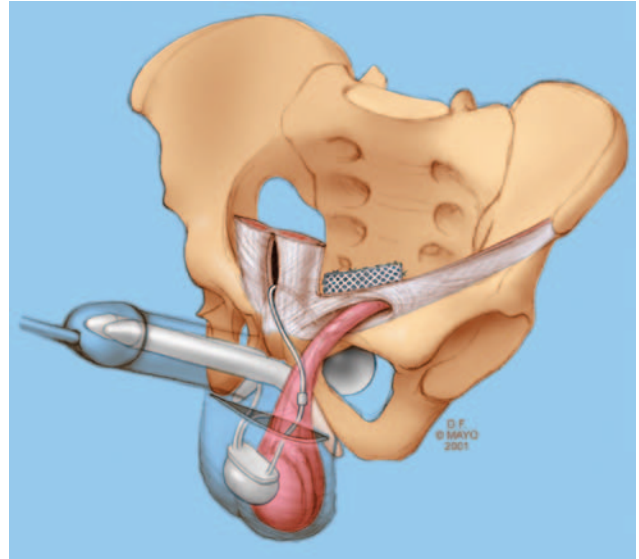


Figure 78.14 Final appearance of reservoir and tubing when placed through a midline approach.

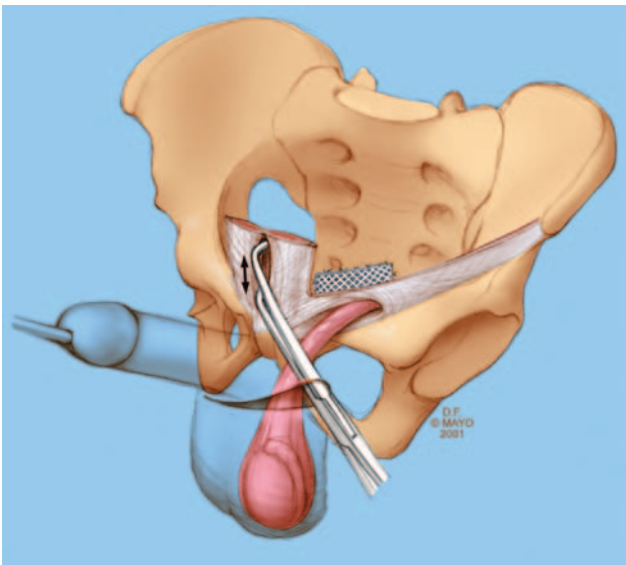


Figure 78.13 Midline placement of reservoir in patient with significant inguinal scarring preventing placement through inguinal ring.

reservoir is then filled to capacity with normal saline. With recent advances in the reservoir's lock-out valves to prevent autoinflation, we typically fill the reservoir with saline to the desired capacity of the reservoir.

The prosthesis is then tested by connecting a syringe filled with saline to the exit tubing of the reservoir. This serves as a surrogate reservoir to allow repeated inflation and deflation of the device to ensure good function and cosmesis.

Attention is then directed towards inserting the pump/deflation mechanism into a dependent portion of the scrotum and in the dominant hand aspect (side) for the patient. An incision is made through dartos fascia, and the surgeon's index finger is inserted. The pouch is bluntly created to produce a subdartos pouch for the pump. The pump is then inserted into the pouch so that the deflation mechanism is superficial and anterior (Figure 78.15). The subdartos pouch is then closed with a 3-0 Vicryl suture.

The final connection is then made between the exit tubings of the pump and the reservoir. We perform this connection using the Quick Connector (American Medical Systems, Minnetonka, MN) system using the straight connector. The incision is then closed using a running 3-0 Vicryl for the dartos fascia and 3-0 non-dyed Vicryl suture in an interrupted fashion on the skin. A triple antibiotic cream is placed over the incision and a lightly compressive dressing is applied to the phallic shaft.

The patient is then admitted to the hospital for prophylactic intravenous antibiotics and pain management for the first 23 hours following placement of the prosthesis. The Foley catheter is removed in the morning of the first postoperative day. The patient is encouraged to void and is typically discharged 23 hours after the procedure. We recommend that the pump is pulled into a dependent portion of the scrotum on a daily basis for the first 3 weeks to prevent proximal migration of the pump. The patient is

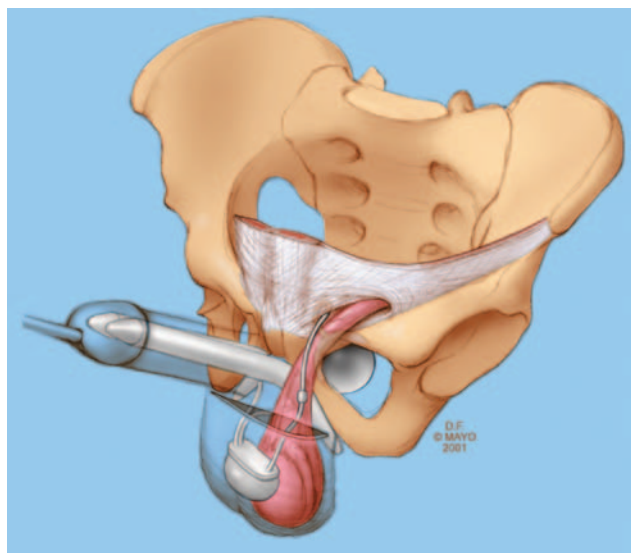


Figure 78.15 Final appearance of three piece prosthesis with reservoir placed through inguinal ring.

instructed to avoid sexual activity for 3–6 weeks and return to our office 3–6 weeks following placement of the prosthesis for a physical examination and instructions on device use.

COMPLICATIONS

Complications may occur either intraoperatively or postoperatively in the placement of urologic prosthetics. Recognition, prompt diagnosis and management, and treatment are the mainstay of management of these complications. Surgical experience with penile implants and the challenges of management of prosthetic complications continue to improve with device innovations and modifications. The manufacturers of the devices have been responsive to potential problems and have been quick to adapt revisions to prosthesis design. Despite this, there have been relatively few major revisions in the past 5–10 years indicating most patients and surgeons are satisfied with current designs. Mechanical reliability of the implants is good with repair rates ranging from 10 to 20% at 5 years.^{20–22}

Intraoperative complications

Intraoperative complications may occur with placement of penile prostheses. Prompt recognition and management are important as many of these complications are best managed intraoperatively.

Corporeal crossover

Corporeal crossover may occur during dilatation of the corporeal bodies. During dilatation, the dilating instruments should be passed with caution as the intercavernous septum may be perforated with a surprisingly small amount of force. The tools should pass smoothly with minimal resistance with lateral margins of the dilatation always visualized. Clearly, in cases of corporeal fibrosis, extra care should be taken as the dilatation may be even more difficult secondary to the fibrosis.

Intraoperatively, crural crossover should be recognized if the penis appears bulky on one side, significant disparity in measured corporeal length exists, or if there is blood at the urethral meatus. When this complication occurs, one should confirm that there is no urethral injury. In the absence of urethral injury, correction involves removing the crossed-over cylinder and carefully dilating the correct corporeal body. The cylinder can then be reinserted in the correct position. If the site of perforation is large, closure may be performed using absorbable sutures. In the event of a urethral injury, the catheter should be left indwelling, the procedure stopped, and depending on the site and size of injury, a retrograde urethrogram performed to confirm healing, removal of the catheter, and the patient be brought back for a procedure in 8–10 weeks.

Perforation

Perforation of the corporeal bodies may occur proximally, distally, or into the urethra. In cases of a large proximal perforation, the device should be secured to prevent migration into the perineum. If a proximal perforation occurs with an inflatable device, the input tubing will generally secure the device in place, and no further intervention is required. In cases of a semirigid prosthesis, a perineal direct closure of the perforation may be performed. Alternatively, an artificial ‘wind-sock’ may be fashioned with synthetic material around the proximal portion of the prosthesis.²³

Distal urethral perforations may also occur. If a distal corporeal perforation occurs on the first side of dilatation, the procedure should be abandoned and surgery re-performed in 6–12 weeks. A Foley catheter should be placed, the patient should be kept on prophylactic antibiotics, and a retrograde urethrogram should be performed to confirm resolution of the perforation. There is less agreement on the management of distal urethral perforation at the time of dilatation of the second corporeal body. Most surgeons would recommend placement of the contralateral cylinder, pump, and reservoir with return in 2–3 months for placement of the ipsilateral cylinder. This is possibly

because not placing either cylinder, may result in bilateral corporeal fibrosis, and potential difficulty in future placement of the prosthesis. In either case, copious irrigation of the wound should be performed.

Postoperative complications

Erosion

Erosion of the prosthesis cylinder through the glans or into the urethra is rare but may occur. This may be caused by aggressive use of the device, persistent overinflation, and/or failure to deflate the cylinders after use. It may also be pressure related in patients with poor neurologic feedback and this is of particular concern in both diabetic and spinal cord injury patients. Owing to concerns of erosion, patients with a spinal cord injury with a condom catheter are less often treated with semirigid devices. Various authors have found that the two-piece Ambicor penile implant confers enough girth and rigidity due to its more rigid distal portion, with less risk of erosion and will place it in select patients.^{24,25}

In the absence of infection, distal glandular near erosions with the prosthesis 'crowning' underneath the glans can be repaired with a variety of methods including corporoplasty, tunica vaginalis fascia flaps, and a variety of synthetic and natural materials for corporeal reconstruction.^{26–28} However, urethral erosions and erosions through the glans itself require that the eroded cylinder and possibly all the prosthetic components be removed. Most authors also recommend a temporary proximal urinary diversion, such as a suprapubic tube diversion. After the urethra has healed and no contrast leak is identified on retrograde urethrogram, the cylinder and all other components may be replaced.

Glans deformity

Glans deformity, or superonic transport (SST) deformity, is the result of a poorly supported glans. Most commonly, this is as a result of inadequate length and placement of a cylinder. Correction involves either glandulopexy or remeasurement and placement of a larger cylinder, potentially through the addition of rear tip extenders to correct the deformity.^{29,30}

Infection

Infection is the most common and possibly the most catastrophic complication of prosthetic implantation. Prosthesis infections may result in further surgery, device removal, loss of penile tissue, and even the inability to replace penile prosthesis. The most common source of

Table 78.4 Pathogenic organisms infecting penile prostheses

Organism	Relative frequency (%)
<i>Staphylococcus epidermidis</i>	35–60
<i>Staphylococcus lugdunensis</i>	25–40
<i>Staphylococcus aureus</i>	1–10
<i>Proteus mirabilis</i>	1–10
<i>Pseudomonas aeruginosa</i>	5–25
<i>Escherichia coli</i>	1–10
<i>Serratia marcescens</i>	1–10
<i>Bacteroides</i> species	<1
<i>Candida albicans</i>	<1
<i>Neisseria gonorrhoeae</i>	<1

perioperative infection is the operative wound, though hematogenous and direct spread may occur in a delayed fashion.³¹ There have been reports of infection following other procedures, such as dental work; however, these infections are very rare. The skin harbors many organisms, and cleansing the skin prior to the procedure is of paramount importance. Table 78.4 illustrates the pathogenic organisms that have been known to infect penile implants. The most common organisms are *Staphylococcus* species, especially *Staphylococcus epidermidis*, a common skin inhabitant. Other organisms, including methicillin-resistant *Staphylococcus aureus* and *Pseudomonas aeruginosa*, have also been implicated in these infections. In general, Gram negative organisms represent 20–25% of implant infections.³² Infections by these organisms usually present at an earlier time than those infected with *Staphylococcus* species.³³ Henry et al³⁴ reported a multicenter study of culture of prostheses removed for mechanical failure and found that up to 70% of prostheses were colonized despite no symptoms of infection.

Fortunately, the incidence of clinically significant infections remains low, from 1 to 8%. However, patients who are immunocompromised, patients with diabetes (a common cause of ED), and patients following traumatic urethral injuries are at a higher risk of infection. The risk of infection is also increased for patients with decreased cavernosal vascularity, such as those with severe vascular disease and patients undergoing salvage or repeat procedures.

The presentation of a prosthetic infection is somewhat variable. Persistent pain following recovery at the site of the implant is a common sign of a subclinical infection. Other important signs include cellulitis, fever, chills, and purulent drainage from the area. In advanced stages, the scrotal pump may be fixed to the scrotal wall, and patients may present with Fournier's gangrene and associated systemic shock. In the presence of a clearly infected device, surgical exploration is

required. The use of systemic antibiotics to eradicate a prosthesis infection has been unsuccessful. Often such infections are associated with a biofilm that surrounds the prosthesis.³⁵ This can inhibit phagocytosis and prevent adequate diffusion of antibiotics to the area. In cases where the diagnosis is uncertain or the source of the infection is unclear, a pelvic magnetic resonance imaging (MRI) scan may be helpful to localize or rule out infection of the prosthesis.³⁶ Fluid-filled abscess cavities are easily appreciated with MRI, and the addition of gadolinium contrast enhancement can aid in the identification of inflammation.

Several preoperative and postoperative modifications may be recommended to decrease the incidence of infections. Initially, to decrease the likelihood of infections, it is important to examine patients preoperatively. If the patient has a rash or erythema of the scrotum or perineum, the procedure should be deferred. Next, it is important to prepare the skin adequately preoperatively. We recommend a 5-day course of an antiseptic and antimicrobial surgical scrub such as chlorhexidine (Hibiclens; McInlyke Health Care US, LLC Norcross, GA). The surgical preparation should then be performed for a minimum of 10 minutes. Hair at the operative site is shaved in the operating room with care to avoid small cuts in the skin, which may break the skin's epithelial lining and become a nidus for infection. During the surgical procedure, traffic in the operating room should be minimized. We recommend prophylactic broad spectrum antibiotics to be given intravenously a minimum of 1 hour prior to skin incision. During the procedure, frequent irrigations of the operative site can decrease bacterial counts; we recommend an antibiotic irrigant, such as a bacitracin-neomycin solution (50 000 units of bacitracin and 1 g of neomycin in 1 liter of normal saline).

Hospitalization for 23 hours of prophylactic intravenous antibiotics is also performed, with patients going home with a 1-week prescription of broad spectrum antibiotics.

For those patients in whom penile prostheses become infected despite adequate prophylaxis, newer techniques of salvage have demonstrated increasing success. Explantation of the device with reimplant 6–12 months later has been associated with scarring and penile shortening. Thus, there has been resurgence in salvage, or rescue procedures. A salvage or rescue procedure entails removing the entire prosthesis and foreign material, cleansing the wound with a series of antiseptic solutions (Table 78.5), and placing a new prosthesis at the same operative setting. Long-term follow-up shows that this is successful in approximately 84% of select cases.^{37,38} The purpose of the salvage procedure is to maintain as much penile length as possible, while allowing for an

Table 78.5 Irrigation solutions for salvage procedure

Bacitracin-neomycin antibiotic solution
Hydrogen peroxide (3%)
Betadine (½ strength)
5 liters of pressure irrigation with 1 g vancomycin and 80 mg gentamicin
Betadine (½ strength)
Hydrogen peroxide (3%)
Bacitracin-neomycin antibiotic solution

easier cylinder insertion. This approach is less likely to succeed if the infection is manifested within several weeks of original inflatable penile prosthesis placement, is accompanied by extensive cellulitis, or is caused by particularly virulent organisms. Salvage procedures are not recommended in patients with sepsis, ketoacidosis, or tissue necrosis, and explantation of the device with local debridement should be considered in these cases.

Though largely replaced by the procedure described above, another salvage option is to remove the device completely and place surgical drains in the corporeal bodies bilaterally. The drains may then be irrigated with an antibiotic solution every 6–8 hours for 48 hours.³⁹ After this time period, the patient is taken back to the operating room for an exploration. If purulence or other debris is appreciated, no further surgery is performed. However, if the wound appears clean, it is again copiously irrigated and another implant may be placed.

While standardized sterile techniques, perioperative antibiotics, and careful surgical procedures continue to be the cornerstone of penile prosthesis infection prophylaxis, newer designs of penile prostheses for antibiotic coating have resulted in an improvement in the prevalence and incidence of penile prosthesis infection. Animal studies⁴⁰ have indicated that silicone graft material impregnated with antibiotics, particularly rifampin and minocycline, reduced the incidence of graft colonization.⁴¹ Following these studies, AMS introduced InhibiZone® (American Medical Systems, Minnetonka, MN) antibiotic surface treatment of its three-piece inflatable prostheses. InhibiZone is a surface treatment that is composed of minocycline and rifampin. The mechanism of minocycline (inhibits protein synthesis) and rifampin (inhibits DNA-dependent RNA polymerase) may help reduce the likelihood of developing bacterial resistance to either drug. The treatment gives the prosthesis an orange-yellow tint. The antibiotics elute from the silicone matrix when exposed to a warm, moist environment. This local antimicrobial release may prevent early colonization and the development of a bacterial biofilm layer. A recent study compared the infection rates of 4205 men with or without InhibiZone surface treatment.⁴² They demonstrated an 82% relative

risk reduction in the patients treated compared with the untreated control group (the absolute risk of infection decreased from 0.68 to 1.61%).

In another approach to prevent bacterial colonization, Coloplast Corporation has coated the recent Titan™, a three-piece inflatable prosthesis, in polyvinylpyrrolidone (PVP), a hydrophilic coating that inhibits bacterial adherence. The coating can absorb up to 23 times its weight in water.⁴³ In theory, the antiadherence properties and the ability to absorb water-based antibiotics will reduce the incidence of infection.⁴⁴ An added benefit of this approach is that it allows the surgeon to select the antibiotic in which the device is immersed. Animal studies⁴⁴ have demonstrated that the material limits bacterial growth for up to 3 days, particularly against *S. epidermis*. A clinical study of 2839 patients demonstrated a reduction in the risk of infection from 2.07 to 1.06% with follow-up of 1 year⁴³ when Coloplast's non-impregnated implant (Alpha-1™) was compared with the newer coated Titan. Several additional changes were made with the development of the Titan, thus a direct analysis of the effect of PVP is not available.

An important caveat with any of the clinically available surface treatments is that they are to be used in conjunction with good operative procedures and do not supplant antimicrobial vigilance, sterile technique, or prophylactic antibiotics.

Penile necrosis

Penile necrosis has been reported following placement of a penile prosthesis.⁴⁵ Fortunately, this is a very rare complication and results from diminished blood flow to the corpus spongiosum or corpus cavernosa. Patients with poor peripheral vascularity are more prone to this complication. To prevent penile necrosis, longitudinal incisions on the shaft of the penis are preferable to circumferential incisions. Catheters should not be used for an extended period. Compression dressings on the penile shaft should be placed with care, and the glans should be monitored for signs of necrosis. When this complication is diagnosed, the implant should be removed. The necrotic tissue should be debrided. The glans penis may appear dark or dusky and remain salvageable, so one should not over resect in this area. Warm compresses and peripheral vasodilators may be helpful in improving distal blood flow.

PATIENT AND PARTNER SATISFACTION

Penile prostheses are the most invasive and least chosen treatment for ED. However, when they are placed, the

penile implant has the highest patient satisfaction rate of all the currently available treatments for ED. Conversely, patients who choose to have a penile prosthesis placed have typically failed multiple other options and are more likely to be satisfied with the reliable, spontaneous erection that a penile prosthesis provides.

Patient and partner satisfaction rates are impressive and range from 75 to 100%.⁴⁶ However, these rates are reported from varying measures. Some series report satisfaction from a surgeon interview, others with a mailed questionnaire, and others from a telephone interview. Few series prospectively evaluate change in the frequency of intercourse or use validated instruments in a prospective fashion. Response rates have ranged from 63⁴⁷ to 100%.⁴⁸ Similarly, partner satisfaction rates vary significantly and measures differ. Two series in the literature have addressed these deficiencies,^{49,50} and large prospective, multi-institutional studies are currently underway.

Nonetheless, few people will deny that the vast majority of patients are very satisfied with their penile implant. The main factor contributing to dissatisfaction of the procedure is decreased erect penile size. Other factors contributing to dissatisfaction are a less natural feel, decreased sensitivity and drive as compared with younger years, and partners did not feel that they had as large a role in creating the erection. As expected, those patients undergoing multiple other treatments prior to IPP placement have higher satisfaction rates. One recent well performed study demonstrated that men diagnosed with Peyronie's disease, those with a body mass index (BMI) of more than 30 kg/m², or previous radical prostatectomy have lower satisfaction rates than the general penile implant population.⁵⁰

CONCLUSION

Penile prostheses were introduced over 30 years ago as the first effective treatment for ED. They retain an important role in the treatment when oral medication is insufficient or contraindicated, significant curvature is present, and when injection therapy or vacuum devices are proven unsatisfactory. Although they are the most aggressive and least often chosen form of ED treatment, they have the highest patient satisfaction rate. They provide a predictable and reliable result for virtually every motivated and medically suited patient.

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79 Reconstruction for genital trauma

Genoa G Ferguson and Steven B Brandes

INTRODUCTION

Direct trauma to the genitalia is rare, and usually not life threatening, but can be both psychologically and physically debilitating. As genital function has a strong impact on quality of life, it is important that the treating physician for genital trauma be knowledgeable about genital anatomy, as well as its immediate treatment and eventual reconstruction. Genital trauma, in the civilian setting, is roughly 45% penetrating, 45% blunt, and 10% burns and industrial accidents.¹ The primary goal for treatment is the preservation of function and cosmesis, while minimizing complications.

SCROTAL DEGLOVING INJURIES

While the pendulous nature of the male genitalia, combined with the laxity of the covering skin, helps to protect the genitals from penetrating wounds, it makes the skin vulnerable to degloving injuries. The majority of genital skin avulsion is due to motorcycle or bicycle accidents, but auto-sexual arousal using a vacuum cleaner has certainly been a presented cause. Historically, degloving injuries from farming and industrial machinery were the major cause, but this has decreased dramatically with improved safety measures.

Treatment of genital skin avulsions is very much dependent on the location of the avulsion and the extent of the wound. Avulsion injuries are nearly always along the fascial planes, leaving a clean minimally bleeding tunica vaginalis or dartos surface. The scrotum is very forgiving and defects with up to a 60% skin loss can be primarily closed due to the superfluous, elastic skin. After meticulous hemostasis, as the scrotum can become an expanding vessel of blood, a two-layered closure of the deep fascia and skin is done with an interlocking, running, absorbable suture. A scrotal drain after repair is controversial. Often, resultant scrotal hematomas are in the interstitium of the skin and are not hematoceles. However, our preference is that if hemostasis is not ideal or the patient has a coagulopathy, we place either a Penrose drain or a closed suction drain (e.g. a Blake® drain, Ethicon, Johnson & Johnson, Somerville, NJ). An

antibacterial gauze dressing, such as xeroform, with fluff gauze and a compressive scrotal support should be placed to promote comfort and continued healing.

When the scrotal skin loss is too extensive (greater than 60%), numerous methods can be used for coverage. If the injury to the scrotum is not contaminated, repair should be done at the time of presentation. Local skin flaps, autologous skin grafts, and tissue expanders are all options for scrotal repair. We feel that if possible, split-thickness skin grafting is the repair of choice, due to its ease and excellent cosmetic and functional result (Figure 79.1). To begin the process, the testicles are sutured together in the midline with 3-0 polyglactin (Vicryl) suture to prevent migration and to create a singular structure to ease skin grafting. The thick split-thickness skin graft is then harvested with a dermatome at 15–18 thousandths of an inch, ideally from the interior or anterior thigh, and meshed 1.5 : 1 (which allows not only for full coverage of the large scrotum, but also imitates the rugae of the scrotum). This graft is then placed over the testes and cords, and sutured in place at the perineum and ventral penile base. Multiple interrupted chromic sutures are placed in the graft and underlying tissue to ‘quilt’ it to a fixed position. The ‘neoscrotum’ is then covered with xeroform, mineral oil soaked cotton batting, and fluff gauze dressing. Bolster sutures of purple-dyed 2-0 Vicryl are then placed at the graft margins and tied over the dressings to further immobilize everything. Postoperatively, the patient is kept on bedrest for 2 days, to allow imbibition, and the dressings are removed on postoperative day 4 or 5. The patient then showers twice a day, using a blow dryer on cool or gently patting with a towel to dry the graft.

If the patient is unstable or the nature of the injury prevents immediate repair of the scrotum, the testicle should be wrapped in saline-soaked gauze for protection until surgery. If definitive reconstruction is going to be postponed for more than 1 week or the genital and perineal skin defects are very large, the testicles should be protected in superficial thigh pouches for as long as needed. Thigh pouches not only cover the testes, but improve future scrotal reconstruction, decrease the size of the perineal skin defect (allowing for secondary intention closure), and take away the burden of



Figure 79.1 Creation of neoscrotum following scrotal avulsion injury and testicular thigh pouch creation. (A) Removal of testes from thigh pouches. (B) Testes after meshed split-thickness skin graft.

labor-intensive dressing changes. Most importantly, thigh pouches prevent the testes and cord from getting a thick, fibrous, infected peel of granulation tissue. When this 'rind' of granulation tissue forms, it must be removed down to the spermatic fascia and tunica, prior to skin grafting, freeing up the testes and spermatic cords. If the rind is not removed, the neoscrotum becomes contracted and flattened out into an unnatural non-dependent position. The rind is also chronically infected and is a poor bed for skin graft take.

An alternative to skin grafting is performing a rotational flap from the thigh pouches to create a neoscrotum (Figure 79.2). Although neoscrotal results are cosmetically and functionally good, most patients do not want a staged scrotal reconstruction. Most prefer to leave the testes in the thigh pouches indefinitely, particularly if they are elderly or disabled.

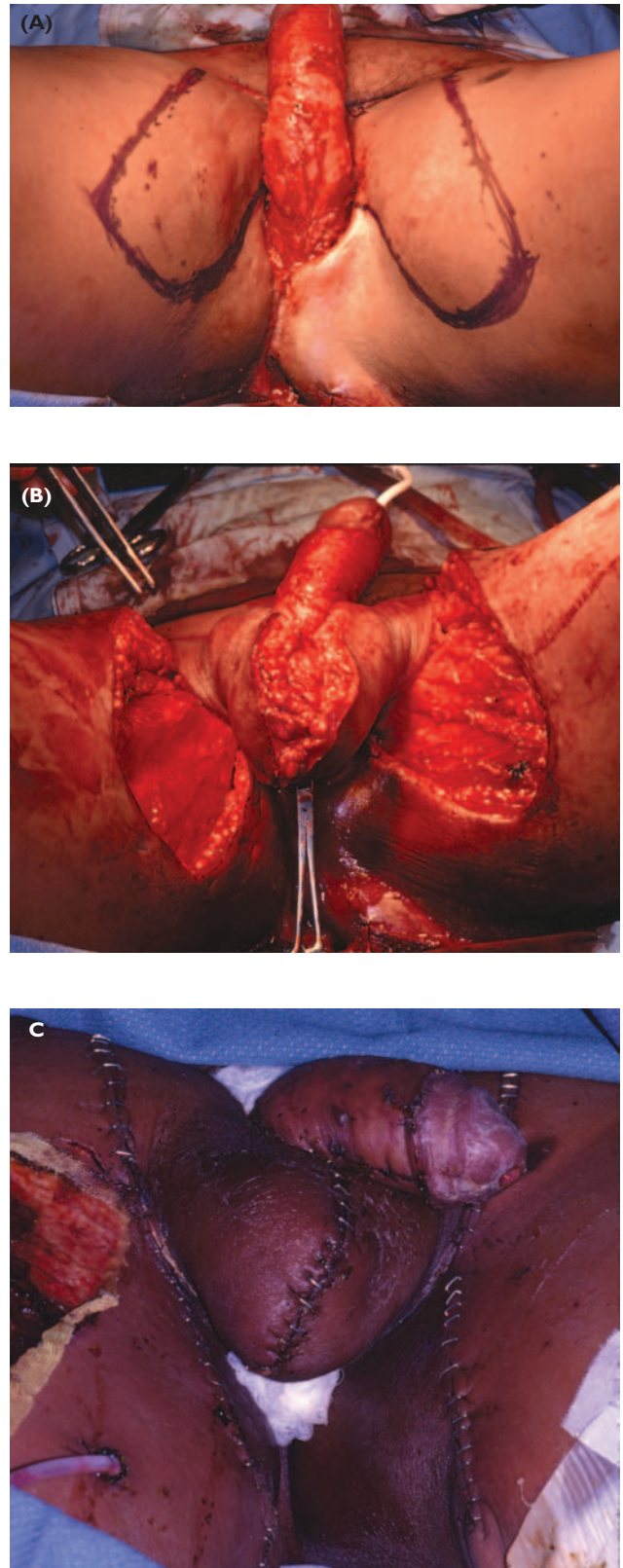


Figure 79.2 Creation of neoscrotum using medial thigh rotational flaps. (A) Patient with testicular thigh pouches, testes outlined. (B) Thigh flaps containing testes have been raised off the thigh and brought together to form neoscrotum. (C) Neoscrotum from medial thigh rotational flaps, immediately following surgery.

To construct thigh pouches, the testis and cord are first mobilized to the external ring. Subcutaneous tissue pockets in the fascia of both of the thighs should be dissected as far posteriorly and caudally as possible, to prevent stretching of the spermatic cord caused by thigh abduction. At this level, the tissue is dissected until the 'shiny' fascia lata of the thigh is identified. The pouch is dissected superficial to the fascia lata with a sponge stick and two narrow deavers into the anterior thigh. If the testes are placed too medially, many patients have discomfort when they place their legs together. The plane should dissect out easily and bluntly. Placing the testes and cord on top of the fascia lata facilitates mobilization later for scrotal reconstruction. If placed superficially or deep to the fascia, tissue in growth is extensive and makes delayed mobilization difficult.

PENILE DEGLOVING INJURIES

Penile degloving injuries can also occur and usually demand immediate reconstruction. Penile skin loss and scrotal skin loss must be treated in very different ways, due to the nature of their function. If possible, as in repair of the scrotum, primary closure of the skin should be attempted. However, the penis does not have the surplus skin that the scrotum possesses and primary closure is often less common. Additionally, penile skin loss is often circumferential, disrupting distal lymphatic drainage. Thus, when circumferential avulsion takes place, the remaining skin must be degloved to the subcorona, otherwise the distal skin will swell with a chronic, disfiguring lymphedema.

Since the penis needs to maintain erectile function, if a primary closure is not feasible, a thick non-meshed split-thickness skin graft should be placed due to its decreased contracture rate. Meshed split-thickness skin grafts, while great coverage for the scrotum, can contract so much on the penis that erections are restricted or bent. The skin graft should be wrapped around the denuded penis with the seam on the ventral aspect of the shaft, to both maximize cosmesis (simulates a median raphe) and help to avoid subsequent chordee. The graft should be immobilized with quilting sutures (we prefer interrupted 3-0 chromic suture). At the proximal and distal ends of the penis, circumferentially at least four sutures of long, purple-dyed 2-0 Vicryl sutures are placed to tie over a bolster dressing.

Xeroform (Petrolatum Gauze, Kendall, Mansfield, MA) or another non-adhesive dressing is then placed on top of the skin graft around the penis, followed by



Figure 79.3 'Penis house' after skin grafting of penis.

a layer of mineral oil-soaked cotton wadding, and then followed by fluff gauze (Figure 79.3). The long sutures are then tied down to hold this large bolster in place. For patients who are particularly active, the bolstered penis can be additionally immobilized by further placing it in a 1 liter plastic saline bottle, with the top and bottom cut off and edges padded around the bolster. This 'penis house' is then sutured at three corners to the abdominal wall with a large cutting-tipped suture. Postoperatively, the patient is cared for like a scrotal skin graft, with bedrest for 48 hours, dressing removal at 4–5 days after surgery, followed by twice daily showers, and gentle drying of the graft with the cool setting of a hair dryer. An alternative, simpler method to immobilize the skin graft is to wrap the fluff dressing with elastic coban and staple the coban periodically while wrapping it around the penis, leaving the glans exposed. The final tight dressing is stapled at the edges of the skin.

If the patient is impotent and elderly, a meshed split-thickness skin graft is fine, particularly if there is a paucity of donor site area. Also, a scrotal flap can be used to cover the denuded penis, if the patient does not mind a hair-bearing penis and is impotent (modified Cecil technique). To create the scrotal flap, a

transverse incision is made in the inferior aspect of the scrotum followed by the creation of a subdartos tunnel. The penis can then be brought through the tunnel with only the glans exposed, covering the denuded penile shaft. The subcoronal skin is then sutured to the scrotal flap edge with interrupted absorbable sutures. Patients later have the option to undergo a second stage procedure to free the penis, which few select.

PENILE AMPUTATION

While the most publicized genital amputations are from violent acts against men, the majority of adult genital amputations are actually self-mutilation done by acutely psychotic patients. Historically, the majority of patients have had schizophrenia, had severe religious delusions, or been transsexuals unable to gain access to sexual reassignment surgery. Additionally, there are case reports in the literature of genital amputations caused by agricultural and industrial machinery accidents. Interestingly, the largest series of reanastomoses of penile amputations was reported in Thailand. During the 1970s, there were an estimated 100 penile amputations by angry wives against their filandering husbands, with 18 having been replanted by the same medical center.

Depending on the damage to the amputated penis, there are three ways to manage the injury: closure of the remaining stump, surgical replantation of the amputated penis, and total phallic replacement. If the amputated penis is viable, penile replantation should always be attempted, even if a patient refuses the treatment, as their psychiatric state at the time does not allow for proper decision making. The amputated penis should be carefully cleaned and debrided with either normal saline or lactated Ringers and then cooled in a 'double bag'. The 'double bag' method, involves wrapping the cleaned penis in saline soaked gauze, placing in a sterile sealed bag, and then keeping the bag in another bag or basin of ice-slush. This not only maintains hypothermic conditions, optimally at 4°C, but also protects the penile skin from direct contact with ice. As success has been reported after 16 hours of cold ischemia and 6 hours of warm ischemia, we feel that penile replantation should be attempted up to 24 hours after the injury.

Upon presentation, the patient must primarily be stabilized, with aggressive fluid resuscitation, a complete blood count checked, and blood transfusion if the blood loss was extensive. Whenever possible, the patient should be brought to a center that can perform

microvascular surgery, as it has considerably better results than a macrovascular approach. Microvascular reattachment has been shown to have decreased skin necrosis and glans slough, improved sensation, and improved function.

To perform replantation, first obtain vascular control of the base of the proximal cut edge of the corpora (Figure 79.4). Depending on the extent of the bleeding, manual local compression with gauze or a Penrose drain tourniquet may be necessary. After the bleeding is controlled, the tunica albuginea of the corpora cavernosa are reapproximated with interrupted 3-0 polyglactin (Vicryl) suture, with three to four sutures through the median septum for stabilization. The central cavernosal arteries do not need reanastomosing, as this is both technically difficult and does not improve outcome. The proximal and distal urethral edges are then mobilized off the corpora and the ends spatulated. The urethra is then reanastomosed over a 16 Fr silicone Foley catheter with interrupted 5-0 polydioxanone (Maxon or PDS) suture in a single layer. We then typically place a suprapubic tube to proximally divert the urine for healing.

Once the penis is stabilized, the microscopic reanastomosis of the vasculature begins, often by a plastic surgeon or a urologic surgeon with microvascular training (e.g. an infertility specialist) who does this more often in their personal practice. First, the deep dorsal vein is reanastomosed with 11-0 nylon or polypropylene (Prolene); this anastomosis must be patent to prevent corporeal edema, swelling, and subsequent edema. Second, at least one, preferably both, of the dorsal penile arteries are reapproximated end-to-end in the same manner as the vein, which immediately restores blood flow to the subcutaneous tissues and prevents postoperative skin necrosis. Blood flow measured by Doppler through the dorsal arteries needs to be established prior to leaving the operating room. Finally, as many nerve fibers as can be identified are then reapproximated with a simple nylon or polypropylene suture in the epineurium, allowing the fascicles to heal secondarily.

Depending on the state of the amputated penile skin, the skin edges are either reapproximated with interrupted 4-0 chromic sutures or a thick, non-meshed, split-thickness skin graft is placed if the penile skin is unusable or denuded. If neither of the above methods is possible, a last resort is to bury the penis in a subcutaneous tunnel in the scrotum (using the previously described modified Cecil technique), which leads to a suboptimal hair-bearing, thick-skinned penile shaft, which requires a second reconstructive

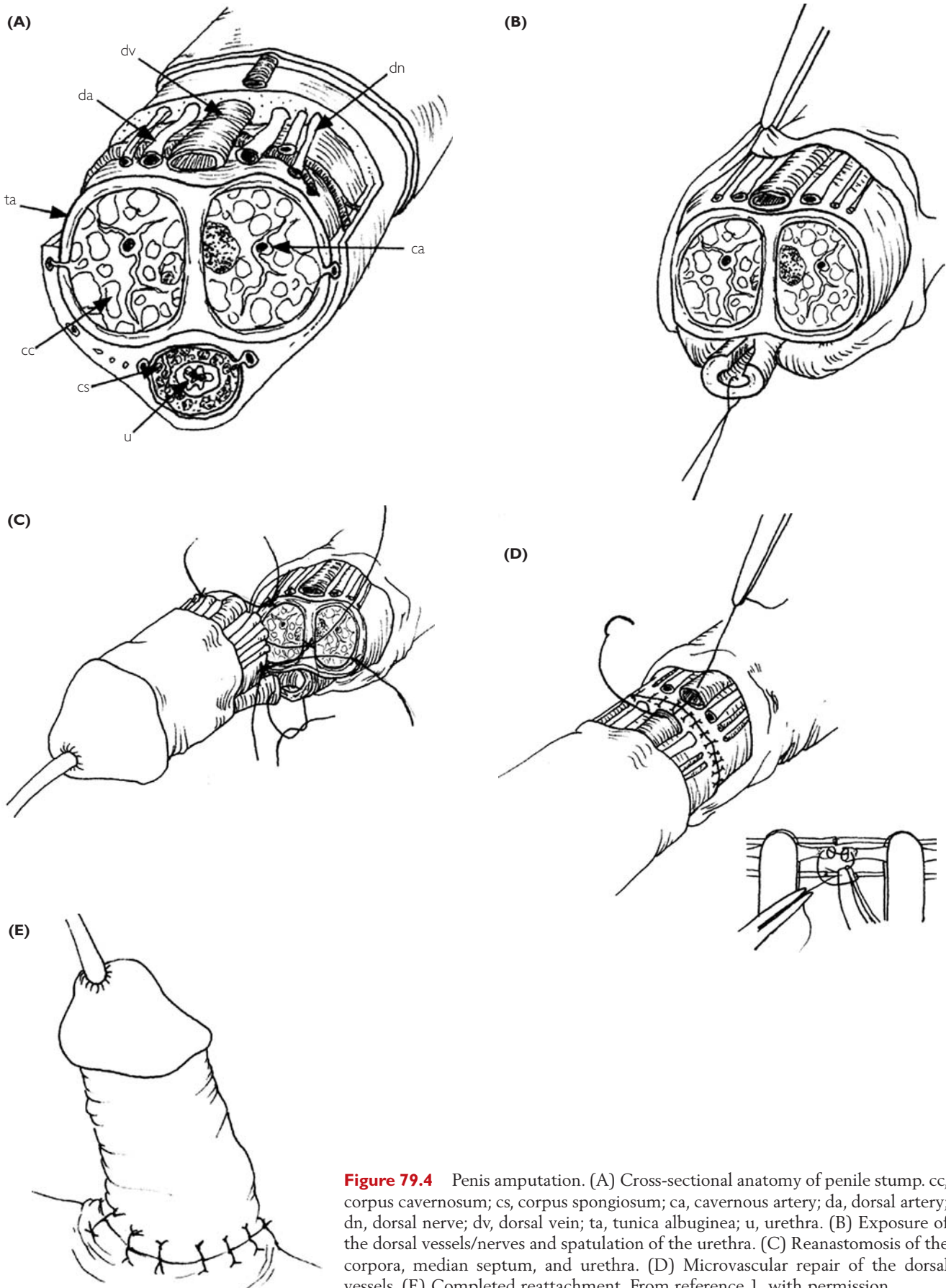


Figure 79.4 Penis amputation. (A) Cross-sectional anatomy of penile stump. cc, corpus cavernosum; cs, corpus spongiosum; ca, cavernous artery; da, dorsal artery; dn, dorsal nerve; dv, dorsal vein; ta, tunica albuginea; u, urethra. (B) Exposure of the dorsal vessels/nerves and spatulation of the urethra. (C) Reanastomosis of the corpora, median septum, and urethra. (D) Microvascular repair of the dorsal vessels. (E) Completed reattachment. From reference 1, with permission.

surgery. Nonetheless, it is imperative that the vascular anastomoses are covered to prevent delayed vessel thrombosis and resulting replantation failure. Finally, the penis is wrapped in loose dressings and an external splint fashioned to facilitate venous and lymphatic drainage.

If a patient does not have access to a medical center with microvascular capabilities, then a macrovascular reattachment can be attempted. This is certainly sub-optimal, for the above stated reasons, but is a better option than not attempting reattachment and defaulting to a penile stump. Often, if the dorsal vein of the penis can be reanastomosed, the penile skin and glans may not necessarily slough. If penile replantation is not an option, then the penile stump can be closed as for a standard elective partial penectomy. A free forearm phalloplasty can be performed at a later date, at the patient's request.

Postoperative management must include at least 2 days of bedrest and perioperative broad spectrum antibiotics. After at least 2 weeks of urethral stenting, the Foley can be removed after a pericatheter retrograde urethrogram or a voiding cystourethrogram verifies a healed anastomosis; the suprapubic tube is then removed after a few days of normal voiding. Besides surgical management, the psychiatry department must be closely involved with this patient's care. Genital self-mutilation is always irrational and the patient's mental health must be addressed. There is also a higher suicide rate among people who self-amputate their genitalia and these patients must also be closely monitored.

TESTIS AMPUTATION

While the penis, if properly cooled, can be successfully replanted, the testes are much more temperamental. Due to their highly metabolic state, the testes have only a 4–6-hour period of time following amputation for successful replantation.

To begin replantation, the two edges of the spermatic cord should be debrided and, within both ends, the spermatic veins, the spermatic artery, and the vas deferens must be identified. Under the microscope, the spermatic artery is anastomosed together using an 11-0 nylon or Prolene suture. Following this successful reanastomosis, the spermatic veins will begin to bleed on the testicular side and can be identified. Then at least two veins should be joined together with their severed counterparts. Finally, the vas deferens needs to be repaired by doing a vasovasostomy in an end-to-end

fashion. This should be done in a two-layer fashion, connecting first the vasal mucosa using 10-0 nylon or Prolene suture and then the vasal muscularis using 9-0. The spermatic fascia is then closed primarily, to protect and support the fragile anastomoses and an orchiopexy is performed to fix the testicle in place. If the native scrotal skin was not removed with the testicle, the scrotum should be closed primarily over the reattached testis. However, if the scrotal skin was amputated along with the testicle, then the replanted testicles should be placed in thigh pouches until a neoscrotum can be made, in the method described above for scrotal avulsion.

As with penile amputation, these patients must be closely cared for following replantation surgery. Auto-castration is commonly accompanied by re-emasculature and is seen mainly in psychotic patients and transsexual patients who lack proper medical access. Psychiatry must be intimately involved in these patients' care, as they have severe mental illness and are likely to repeat their actions if not properly treated.

PENILE FRACTURE

Fracture of the penis is a rupture of the tunica albuginea of the corpus cavernosum, usually while the penis is rigid and erect. When erect, the tunica albuginea stretches and thins to 0.25–0.5 mm thick, compared with 2 mm thick when flaccid. Thus, the erect penis is much more vulnerable to serious damage from blunt trauma than the pendulous, flaccid penis. The most common cause in the Western hemisphere is vigorous vaginal intercourse, often when the woman is on top and the penis is susceptible to acute bending. In the Middle East, however, the most common cause of fracture is non-coital penile manipulation in an attempt to achieve rapid detumescence. The classic presentation described by patients is a cracking or 'popping' sound, followed by rapid detumescence, severe pain, ecchymosis of the penile skin, and swelling of the affected side with deviation away from the affected side. In most cases, the penile fracture is a transverse corporeal tear, close to the corpus spongiosum, on the ventral aspect of the penis (Figure 79.5). Many patients have delayed presentation due to embarrassment and it is suspected that some patients with minor corporeal tears never present at all.

Penile fracture is considered by most to be a clinical diagnosis, with little need for imaging if the patient presents with a convincing history and physical



Figure 79.5 Penile fracture after degloving and exposure of torn corpora carvenosum and urethral transection.

examination. While there are numerous reports of the accuracy of cavernosography and magnetic resonance imaging (MRI) of the penis to diagnose the injury, we have found such methods too invasive, cumbersome, or costly to justify, particularly when the diagnosis can be made based on clinical presentation. Admittedly, rupture of the dorsal vein of the penis can present after penile trauma and can closely mimic penile fracture with ecchymosis and deformity, but we still feel that diagnostic imaging should be limited. However, if urethral injury is suspected, retrograde urethrography or flexible cystoscopy should be done to further assess for damage. Urethral injury has been reported in 10–38% of penile fracture cases, due to an extension into the corpus spongiosum, causing laceration or complete transection of the urethra. Any signs of urethral injury, such as inability to void, blood at the urethral meatus, or any hematuria (gross or microscopic) should cause a high level of suspicion in the physician and warrant further evaluation.

Due to the low complication rate and reportedly good outcomes by numerous centers, immediate surgical repair is the favored approach for treatment of penile fracture. While conservative management may be an option in patients with uncomplicated tears of the tunica albuginea without extensive hematoma or urethral injury, most untreated fractures develop delayed and persistent penile pain or curvature with erection.

Surgical repair of the penile fracture first entails exposure of the defect in the corpora cavernosum and the urethra, due to the concomitant 20% urethral injury. The individual patient's injury can guide the exposure incision, but options include a circumferential, subcoronal, degloving incision of the penile skin or a longitudinal incision directly over the injury exposing

only the tunical tear. Following exposure, the hematoma should be evacuated, any bleeding controlled, and the fracture site debrided. Primary closure of the corpora can usually be performed using a running absorbable suture, such as 2-0 Vicryl. If the location of the corporeal tear is not obvious, a Penrose tourniquet can be placed at the penile base and a butterfly needle placed into the corporeal shaft and flushed with saline. Extravasating saline identifies the defect to repair.

Complete urethral transections should be repaired (reanastomosed) immediately, with the ends debrided, spatulated, and approximated tension-free over a urethral catheter. If there is a partial disruption of the urethra, then depending on the extent of the tear, a 'stenting' urethral catheter can be placed, a suprapubic tube can be placed, or primary repair of the tear can be done. Urethrography is performed after a couple of weeks to confirm urethral healing.

TESTICULAR RUPTURE

A testicular rupture is defined as a rupture of the tunica albuginea with extrusion of seminiferous tubules. While rupture can be due to penetrating etiologies (i.e. gunshot and stab wounds), most injuries are via a blunt mechanism. Most testicular ruptures occur in 10–30-year-old males during sports-related activity.

While penetrating injuries deep to the scrotal dartos fascia are all surgically explored, it is not necessary to surgically manage all blunt injuries. Many hospitals will clinically manage injuries that do not show clinical or radiologic evidence of rupture. Scrotal ultrasonography previously was found to be poorly diagnostic. However, in the hands of a well-trained sonographer, the radiographic finding of a heterogeneous echo pattern of the testicular parenchyma with loss of contour of the testis tunica was recently shown by the San Francisco General Group to have 100% sensitivity and a 93.5% specificity (Figure 79.6A). Injuries that are clinically benign and are homogeneously echogenic by ultrasound do not necessitate surgical exploration (Figure 79.6B).

If a testicular rupture is present, urgent surgical management is important for salvage of the testicle. Unless the viable tissue is inadequate for repair, the surgeon should repair whatever remaining viable tubules remain. Studies have shown that repair of remaining tubules prevents endocrine abnormalities and decreased semen quality compared with orchiectomy. Historically, blunt ruptured testes explored promptly (less than 72 hours) have a salvage rate of

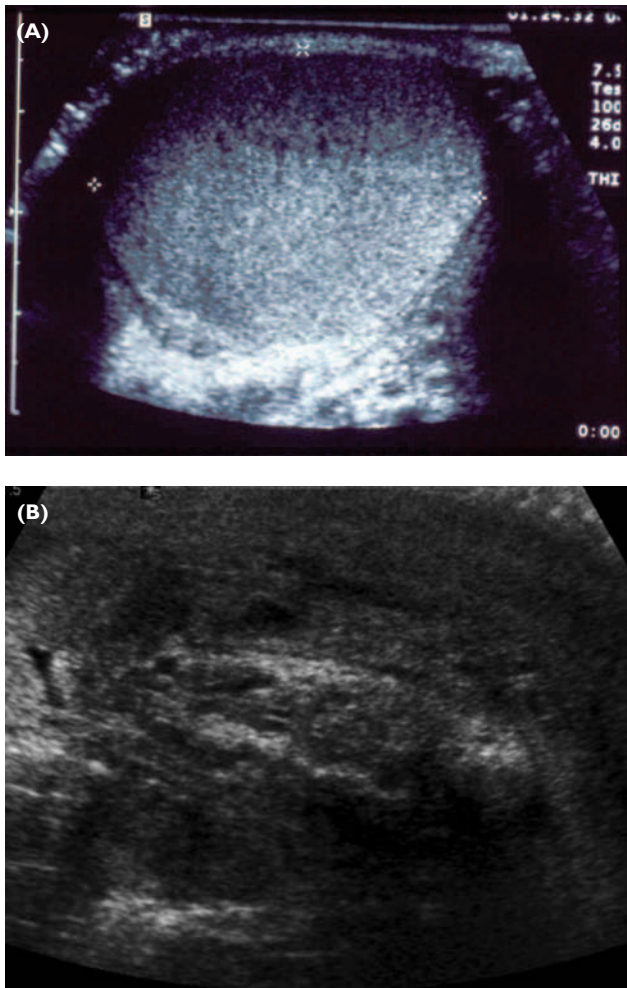


Figure 79.6 (A) Normal ultrasound of testicle, note homogeneous testicular tissue. (B) Ultrasound of ruptured testicle, note heterogeneous testicular tissue and disrupted tunical contour.

over 90%, while those explored late have a poor 45% salvage rate.

To repair the testicle, the scrotum is typically explored through a long vertical incision in the median raphe. This allows maximal exposure to both testes and cords. The tunica vaginalis is opened and the testis is opened and brought out of the scrotum and the injury to the testicle identified. The non-viable seminiferous tubules should then be sharply debrided and any hematoma drained, leaving only healthy bleeding edges. The tunica albuginea is then closed, using a running 3-0 absorbable suture (e.g. Vicryl). The testis is then placed back in the scrotum, with care taken not to place the testis under any torsion, and the scrotum is closed in two layers with absorbable suture. If hemostasis is a concern, a Penrose or closed suction drain

should be placed through a separate stab incision. The wound should then be covered with fluff gauze and held in place with a compressive scrotal support. Further treatment includes anti-inflammatories, ice to the scrotum, and scrotal elevation. If the testicle is found to have only scant viable tissue, then an orchiectomy should be performed. However, all attempts should be made to salvage the testicle, if possible.

PENETRATING WOUNDS

Penetrating wounds to the genitalia are rare, but increasing in frequency. The majority of wounds are gunshot wounds but stab wounds certainly are causes. During wartime, the vast majority of genital gun shot wounds were concomitant with wounds in other locations, while civilian violence has a higher incidence of isolated genital trauma. Additionally, while military gun shot wounds are from high-velocity weapons, the vast majority of gun shot wounds reported were from low-velocity weapons, causing less damage and allowing for improved repair. With an associated urethral injury rate of up to 50%, all patients with penetrating penile wounds should also undergo retrograde urethrography or urethroscopy.

Treatment of the penetrating wound, for both the penis and the testes, is early surgical exploration, debridement, and primary repair of any injuries. Repair of a penile penetrating wound is very similar to that of a penile fracture. Depending on how distal the wound is, direct visualization of the corpora can be obtained via a circumferential, degloving, subcoronal incision, or via a penoscrotal, infrapubic, or perineal incision for more extensive wounds. For simple injuries to the corpora, primary closure is sufficient for repair, as discussed with penile fracture. However, if there is an extensive defect, a more involved repair must be undertaken.

Testicular injury from a penetrating wound also follows the same principles as that from a rupture from a blunt injury. In general, one-half of gun shot wounds to the scrotum strike the testis; of those injured, one-half of testis are viable enough for reconstruction. Salvage of viable testicular tissue is the primary goal of the repair. After debridement of the non-viable tissue, the tunica albuginea should be closed primarily. However, sometimes the mechanism of the injury, particularly a blast, can cause significant destruction of the tunica albuginea, while sparing underlying healthy seminiferous tubules. When there is not sufficient testis tunica albuginea to primarily close, we recommend using a

free graft of tunica vaginalis to cover the defect and preserve the testicle. This graft can easily be harvested and sewn to the edges of the remaining tunica albuginea for coverage (Figure 79.7). We previously attempted synthetic grafts (i.e. gortex), but had problems with infection and eventual orchiectomy, so we feel that using the native tunica vaginalis tissue is the optimal tissue for coverage, and a clear alternative to orchiectomy.

GENITAL/PERINEAL BURNS

Burns of the genitalia and perineum are seldom isolated and almost always involve other portions of the body. Although the genitalia alone represents 1% of total body surface area (TBSA), studies have shown that patients with perineal burns usually have other injuries and an average TBSA of 21–55%. Initial management of perineal burns is that of any severe burn, with aggressive fluid and electrolyte management and Foley or suprapubic tube placement to monitor adequate urine output. Burns should be treated according to the mechanism of injury and depth of injury.

First-degree burns are epidermal only and are characterized by pink color, with minimal histologic damage, but significant pain. First-degree burns do not have long term scarring. Second-degree burns are divided into superficial partial thickness and deep partial thickness. Superficial partial-thickness burns involve the epidermis and part of the dermis and present as pink, moist, tender skin with thin-walled blisters. Deep partial-thickness burns include the reticular dermis and present with mottled red and blanched white skin with thick-walled blisters and tender skin. Third-degree burns are full-thickness burns that involve the epidermis and the entirety of the dermis. Third-degree burns are characterized by a white or black, dry skin that is numb.

Thermal burns of the genitals are caused mainly by flame, but also by boiling water and grease. These burns tend to be first-degree or second-degree and can be treated without debridement and only with a simple topical antimicrobial, usually 1% silver sulfadiazine ointment. Genital third-degree burns should be treated with prompt surgical intervention, as conservative management only leads to increased infection rates, longer recovery time and hospital stays, and burn scar contracture.

Third-degree burns to the scrotum should be promptly debrided of all non-viable tissue and then immediately skin grafted, as discussed above for

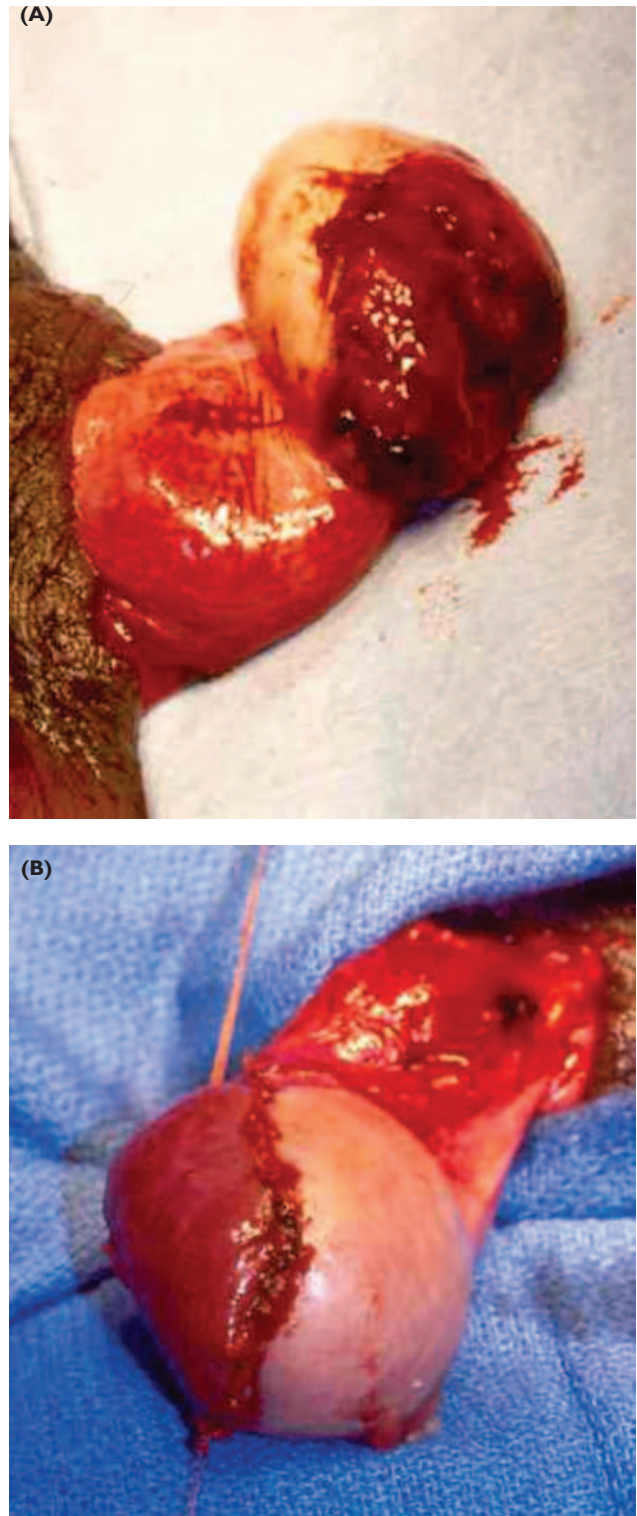


Figure 79.7 (A) Testicle after gun shot wound, note the insufficient testis tunica albuginea for primary repair. (B) Testicle after successful graft with tunica vaginalis.

degloving injuries. With immediate treatment, infection is usually not an issue and there is no reason for a delay in scrotal reconstruction and thigh pouch creation.

The penile skin is very thin and vulnerable to third-degree, full-thickness burns. Should this occur, the non-viable skin should be sharply debrided, the wound primarily closed, and skin grafted to the denuded site (Figure 79.8). Should a circumferential penile injury occur, severe lymphatic obstruction and lymphedema can result, so all distal skin from the injury site to the subcorona should be excised. Burns to the glans, however, usually do not need debridement unless it is absolutely necrotic, due to the excellent vascularity. Additionally, patients with third-degree burns to the glans or the ventral shaft of the penis should have suprapubic tubes, instead of Foley catheters. Foley catheters in these patients can cause pressure necrosis resulting in severe hypospadias due to anterior urethral slough, especially when left in a dependent position.

Thermal burns can be complicated in the long term by urethral slough, urethral stenosis, and eventually scar contracture at 3–6 months postinjury. These are treated with surgical release and skin grafts to the wounds. Chemical burns should be managed with immediate removal of any clothing and aggressive flushing with generous amounts of sterile water. Although many authors recommend neutralizing agents for the particular chemical, this takes unnecessary time and the patient would be better served with sterile water. Electrical burns can be devastating, as the degree and the depth of the burn can be deceptive. The extent of the burn is often beyond what the visible surface burn displays and an extensive exploration of the deep and surrounding structures must be undertaken to evaluate the burn. Work-up for perineal burns can include sigmoidoscopy, cystoscopy, vaginal speculum examination if applicable, and pelvic X-ray to examine for any related bladder, rectum, pelvic organ, or skeletal damage from the electrical injury. Hemoglobinuria and myoglobinuria should also be ruled out with urinalysis to avoid additionally renal damage. Additionally, electrical injuries have been known to cause cardiac arrhythmias that must not be overlooked.

Treatment of electrical burns should include intravenous fluid resuscitation, urine alkalinization, and if necessary intravenous mannitol, until the urine clears of the hemochromogens. Then, these burns should be managed as a thermal burn, with prompt debridement, primary wound closure, and skin grafting. However, these burns often need repeat debridement, due to the often extended damage that they cause. With serial debridements, these wounds can be eventually closed with skin grafts, without unnecessary pain or infection. Sometimes the debridement can be extensive, and bone or major vasculature is exposed in

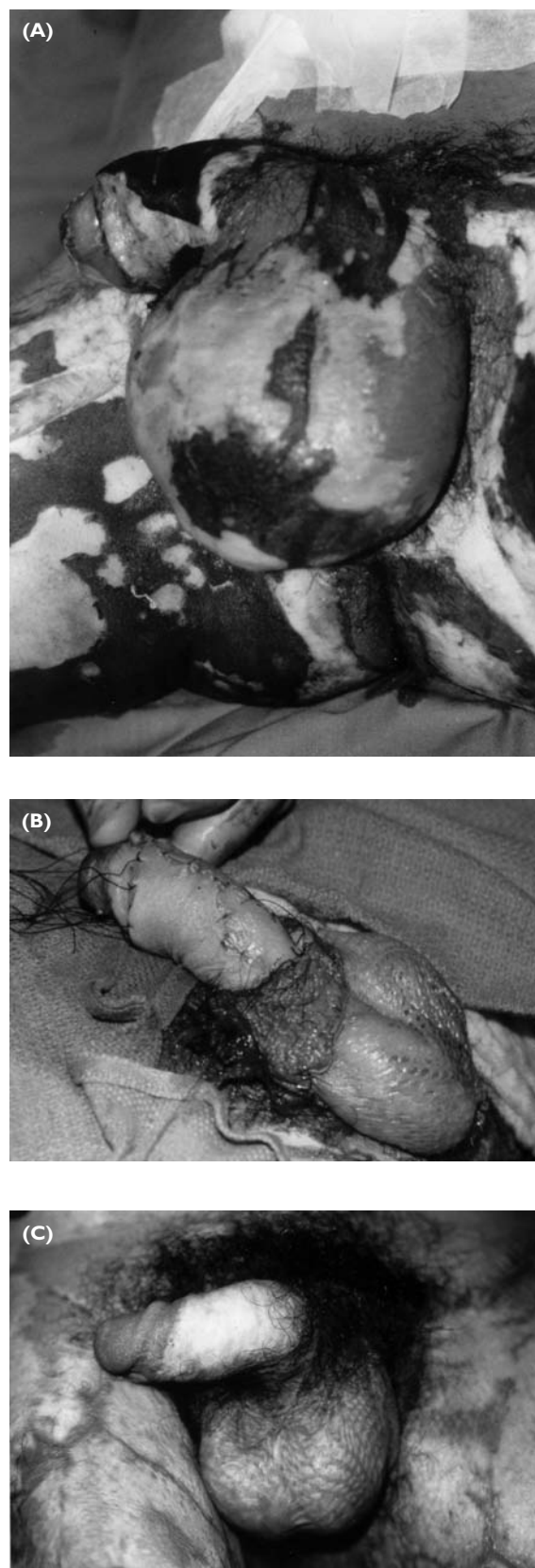


Figure 79.8 Skin grafting of third-degree burn to genitalia. (A) Genitalia and perineum with third-degree burns. (B) Genitalia immediately following skin grafting to penis and scrotum. (C) Genitalia 6 months following successful skin grafting.

the wound. Myocutaneous flaps for coverage may be necessary at that point.

CONCLUSION

Although usually not life threatening, traumatic injury to the genitalia needs to be taken very seriously. It is essential that the treating physician has a thorough knowledge of both the anatomy and physiology of the genitalia in order to make proper decisions about treatment. Rapid and appropriate treatment of the injuries can ensure an improved outcome for the patient, good cosmesis, and excellent function.

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80 Reconstructive surgery in penile cancer

Nicholas Watkin

INTRODUCTION

Penile carcinomas are rare. The incidence in England and Wales is 1.2–1.5 per 100 000 per year.¹ This represents less than 1% of all male malignancies and is comparable with other west European and North American countries. In contrast to this, the incidence in some parts of the developing world is as high as 20 per 100 000 per year. More than 95% of penile malignancies are primary squamous cell carcinomas (SCC), the rest being melanomas, sarcomas, and basal cell carcinomas. Treatments are not well defined because of the absence of any large randomized trials due to the rarity of the disease in developed countries. Guidelines are often based on small retrospective reports. In fact, until recently, specialist referral centers may only have had experience of 100–200 patients accumulated over many years.

Radical surgical therapies have stood the test of time, and excellent local control rates have been achieved. These are, however, associated with significant psychologic morbidity and sexual dysfunction.² Radical radiotherapy preserves the penis but it never looks or functions normally again, and in 20–40% of patients salvage surgery is required for local recurrence. A variety of therapeutic strategies have recently been developed to overcome these problems. They attempt to preserve as much of the penile tissue and functional integrity as possible, without compromising oncologic control. Early diagnosis is a key factor in the selection of such treatments. In the UK, where only 15% of tumors deeply invade the corpora at presentation, the vast majority are amenable to these organ-conserving treatments. This is probably true for all Western, developed countries, but in areas with less well developed health care, patients often present with more advanced disease and some of the reconstructive options detailed in this chapter may not be possible.

DIAGNOSIS AND STAGING

The presentation of penile carcinomas is variable. The primary lesion may present as a red patch, phimosis,

painless ulceration, or nodular growth. An inguinal mass is also not an uncommon presentation. Site, size, morphology, and location on the penis need to be assessed. An assessment also has to be made of infiltration into regional structures. Of particular importance is invasion into the corpora cavernosa, which can be assessed by diagnostic imaging. Both ultrasound scan and magnetic resonance imaging (MRI) have been evaluated, but their benefit has not yet been proven.³ A recent report suggests that penile MRI with induction of an artificial erection accurately predicts corporeal invasion in nearly all cases in which it is subsequently confirmed histologically.⁴

The clinical difference between benign and premalignant lesions is subtle. Invasive tumors are normally clinically obvious but can be difficult to diagnose post-radiotherapy. Furthermore, invasive tumors and carcinoma in situ (CIS) coexist in 25% of cases. Histologic diagnosis is therefore mandatory, which not only confirms the pathologic diagnosis but also the tumor grade. The type of biopsy used is usually determined by the physical nature of the lesion as well as the preference of the clinician and pathologist. Small lesions on the prepuce are suitable for excisional biopsies, whereas larger lesions on the glans require incisional biopsy. The biopsies need to be directed and generous to demonstrate adequately the depth of invasion and not under-stage the tumor.

Patients who have had radical radiotherapy are susceptible to deep necrosis after biopsies.⁵ Management of this is difficult and requires radical surgery in 50% of cases. It is possible on the basis of clinical examination, imaging, and biopsy to be quite confident of the disease stage. The TMN staging system for penile cancer was revised by the International Union Against Cancer (UICC) in 2002 and the T stage is summarized in Table 80.1. The reconstructive surgical options broadly follow the local disease stage. However, in our experience, a subdivision of the T2 category is clinically relevant. Tumors involving the glans spongiosus and those in which disease extends into the corpora cavernosa are very different entities but are currently all classified as T2 lesions. The distinction between glans confined and more extensive disease is very

Table 80.1 TNM classification of penile carcinomas 2002

A Primary tumor	
Tx	Primary tumor cannot be assessed
Tis	Carcinoma in situ
Ta	Non-invasive verrucous carcinoma
T1	Invades subepithelial connective tissues
T2	Invades corpus spongiosum/cavernosum
T3	Invades urethra
T4	Invades adjacent structures

important when considering a patient for reconstructive surgery.

RATIONALE FOR PENILE PRESERVING SURGERY

It is without doubt that traditional treatments have a significant effect on the psychosexual functioning of a patient. Few urologists would dispute the place of conventional amputative surgery in the treatment of stage T4, high-grade stage T3, or proximal-stage T2 disease. Many, however, have started to question the need to perform this procedure in less advanced cases and in cases with more favorable histology. Recently, several reports have been published that challenge the need for a 2 cm margin of clearance. Hoffman et al examined surgical specimens from 14 patients who had conventional surgery for penile squamous cell carcinoma.⁶ In a 33-month follow-up, no patients developed recurrence, and this included seven patients in whom the margin was less than or equal to 10 mm. Agrawal et al reviewed 62 partial and total penectomy specimens, looking for tumor extension into the proximal 2 cm clearance margin.⁷ They found that of the 52 grade 1 and 2 tumors, only seven had positive margins at 5 mm away from the macroscopic lesion. Three out of the 12 grade 3 tumors had extensions up to 10 mm from the visible tumor. In a further study of patients undergoing penile preserving surgery, 90% of patients had margins within 20 mm and 48% within 10 mm. The local recurrence rate was 4%.⁸ This evidence has encouraged the development of penile preserving therapies. Furthermore, most recurrences are surgically salvageable and local failure does not seem to compromise long-term survival. In our unit over the past 6 years we have developed and reported upon a number of procedures which can be offered to

Table 80.2 Procedures performed in the author's unit (300 consecutive cases 2001–6)

	Percentage
Topical chemotherapy for in situ disease	9
Total glans resurfacing for in situ disease	6
Circumcision alone	7
Wide local excision (with or without graft)	12
Glansectomy (with graft)	32
Glansectomy and distal corporectomy (with graft)	20
Partial penectomy	4
Radical penectomy	8.5



Figure 80.1 Precancerous change has been highlighted extending onto the glans penis after soaking in 5% acetic acid prior to circumcision for a small tumor in the prepuce.

patients with squamous carcinoma of the penis at different stages of the disease (Table 80.2).

PENILE PRESERVING TECHNIQUES

Precancerous disease and verrucous carcinoma (Tis and Ta)

Intractable in situ disease or non-invasive verrucous disease can be effectively treated with total glans resurfacing (Figure 80.2A–D). This technique was first described by Depasquale et al for the management of severe balanitis xerotica obliterans (BXO) disease but has been adapted by the author's team for Tis/Ta disease.⁹ The glans epithelium and subepithelium are



Figure 80.2 (A) A patient with in situ carcinoma and verrucous change prior to glans resurfacing. (B) The glans epithelium is sharply dissected off the glans spongiosus in quadrants. (C) A partial-thickness skin graft is used to cover the exposed spongy tissue. (D) The appearance after 2 weeks.

sharply dissected off the glans spongiosus under tourniquet control. It is easiest to remove them in quadrants beginning at the urethral meatus and extending the dissection to 1 cm beyond the coronal sulcus. The denuded surface is then covered with a partial-thickness skin graft and the patient is bed rested for 4 days with a urethral catheter. The graft take is excellent, and the cosmetic appearance 6 weeks after surgery is practically normal. The short-term results of the technique have recently been reported and confirm excellent functional outcome and no local recurrence as yet.¹⁰

Carbon dioxide laser vaporization and Nd : Yag laser coagulation are alternatives to glans resurfacing which can result in good local control and satisfactory cosmetic outcome. For extensive disease, however, the glans is left denuded and takes up to 3 months to re-epithelialize and there is no certainty that the basal

cells will not demonstrate malignant potential in the future. For these reasons it is my preference to reserve laser treatment for small patches of in situ change.

T1 lesions limited to the foreskin

Wide local excision with circumcision is sufficient primary curative therapy for preputial disease.¹¹ Adequate clearance margins must be achieved. For more proximal lesions, circumcision margins may have to be extended to the shaft of the penis to ensure adequate clearance.^{12,13} It is the author's practice that in cases of highly suspicious lesions, 5% acetic acid is used to demonstrate all abnormal areas. A swab soaked in the solution is applied to the penis for 2–3 minutes. This stains areas of otherwise possibly hidden penile intraepithelial neoplasia (PIN)

white, and thus guides the margins of excision (Figure 80.1). If carcinoma in situ or PIN is identified extending onto the glans, the prepuce is resected up to the coronal sulcus and the shaft skin approximated close to it. The glanular in situ change can be treated with topical chemotherapy once the circumcision has healed. The choice of drug and the frequency and duration of administration is not uniform. Our unit's preference is for a 6-week course of topical 5-fluorouracil (5 F/U) applied on alternate days. Non- or partial responders are then given imiquimod for a similar length of time. Overall, there is up to 30% local recurrence (new occurrence) on the glans penis. This is usually apparent within 2–3 years of diagnosis. It almost certainly represents a field change in the mucosa. It is therefore mandatory for close follow-up of these patients. It is probable, although by no means proven, that patients with in situ disease, a history of BXO, evidence of active BXO on the glans penis, or who are immunocompromised are at the highest risk of subsequent glanular recurrence.

In instances of coexisting glans CIS, topical chemotherapy with 5% 5FU cream can be used to control the CIS. Again close follow-up is imperative.

Small discrete T1 tumors on the glans penis

Management of these lesions is contentious. An excision biopsy with primary closure of the glans defect may be possible if the lesion is not close to the urethral meatus and leave minimal deformity. Larger lesions may be difficult to close without tilting the glans and causing difficulty with directing micturition. In this case a small skin graft can be used to cover the defect. My preference is to use a full-thickness graft from the base of the penile shaft. For larger defects, a partial-thickness graft from the lateral thigh is taken. However, as with tumors of the foreskin, there is an inevitable risk of further new occurrences on the glans. Recurrence rates of up to 50% have been reported, most occurring within 2 years of resection.¹⁴ Meticulous and regular follow-up is therefore mandatory. Salvage of these recurrences has a high success rate and does not affect the disease-specific survival.^{12,15} Patients at low risk would include those with well differentiated tumors, lack of in situ disease, and an otherwise normal looking glans. Providing patients are adequately educated about abnormal lesions, and close surveillance offered, this is still a reasonable option.

T2 disease limited to the glans penis

Conventional therapy for these tumors would be a choice of penile amputation of varying degree or radical radiotherapy. These patients can now be offered glansectomy as an alternative. In 1996, Austoni et al were one of the first groups to emphasize the anatomic distinction between the corpora cavernosa and corpus spongiosus, and to propose glansectomy as an effective treatment for glans confined penile cancer.¹⁶ Davis et al reported three cases of penile verrucous carcinoma (recurrent), angiosarcoma, and melanoma limited to the glans.¹⁷ All three underwent glansectomy with clear surgical margins. There were no local recurrences at a follow-up of 12–48 months. In all cases, normal erection, sexual and urinary function resumed shortly after the operation. Hatzichritou et al reported seven cases of verrucous carcinomas treated with glansectomy.¹⁸ They reported only one surgically salvaged recurrence at 3 months. All patients were alive and disease free at 18–65 months. The author's team have recently reported the largest series to date. Glansectomy with coverage of the corporeal heads with a partial-thickness skin graft was performed on 71 patients (32% of all referrals). The local recurrence rate was 6% with a mean follow-up of 27 months.^{19,20}

The procedure involves the dissection of glans penis from the corpora cavernosa. A typical tumor invading the glans spongiosus is shown in Figure 80.3A. A circumferential incision is made in the distal shaft skin down to Buck's fascia, and a plane of dissection is developed between the glans and corporeal heads (Figure 80.3B). Frozen sections of the tunica albuginea and distal urethral margins are taken. The urethra is mobilized to allow the meatus to be at the tip of the penis. The shaft skin is sutured 2 cm from the tip, leaving the corporeal heads exposed. These are then covered with a partial-thickness skin graft taken from the thigh. The graft is quilted to the corpora to prevent hematoma formation beneath it (Figure 80.3C). Tourniquet control is used throughout this procedure. A urethral catheter is inserted, and the patient remains on bed rest for 4 days. At this stage, the catheter and quilting sutures are removed, and the patient is usually discharged on the 7th post-operative day. The operation combines good cosmetic appearance with preservation of sexual and urinary function, and importantly without compromising oncologic control (Figure 80.3D). Unlike radiotherapy, it also allows detailed histologic examination of the tumor.

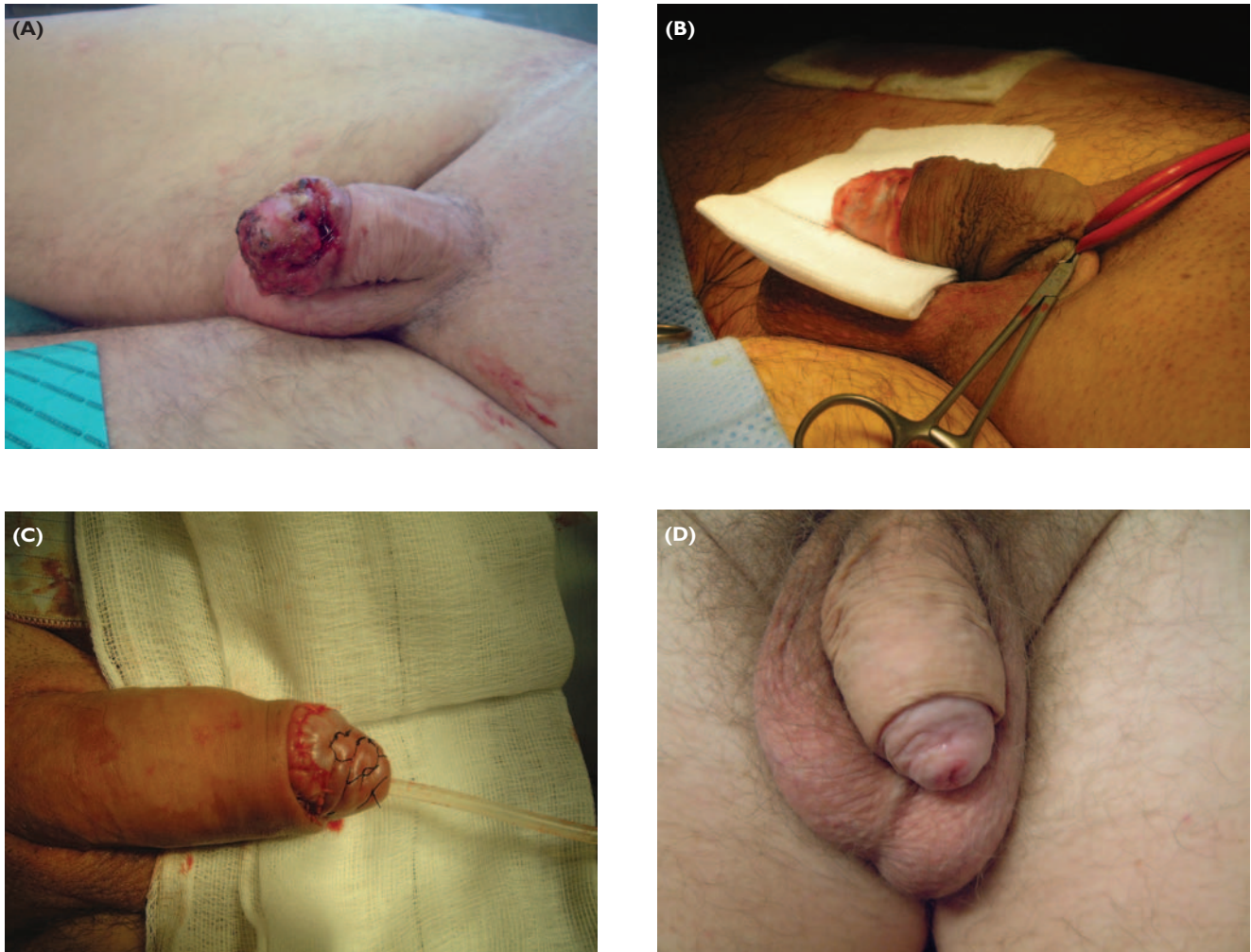


Figure 80.3 (A) A typical invasive squamous penile tumor involving the glans spongiosus. (B) The glans is dissected off the corporeal bodies. (C) The neoglans immediately after surgery with the partial-thickness graft quilted on to the corporeal bodies. (D) The appearance after 2–3 months is cosmetically and functionally satisfactory.

T2 tumors involving corpora cavernosa and T3 tumors

If there is clinical evidence of corporeal involvement before surgery, or frozen sections of the tunica, corpora, or urethra are positive, then a more extensive resection is required. Successive frozen sections of the involved structures are taken until negative margins are obtained. The remaining penis is then assessed as to whether it can be preserved. Up to 2 cm in length may be gained by dividing the suspensory ligaments just below the pubic arch. Alternatively, penile lengthening manoeuvres can be delayed until definitive histology is available. The corpora are then reconstructed to create a neoglans. If there is tethering of the stump by the shaft skin it can be released to prevent any

subsequent loss of length due to traction. The denuded corpora are then covered with a partial-thickness skin graft, from the tip of the neoglans to the mobilized shaft skin. Around 20% of our patient group have a degree of corporeal resection with confirmed corporeal involvement. The cosmetic outcome is better than for conventional surgery; however, case selection is important and close follow-up is mandatory. Clearly the more extensive resections are associated with less patient satisfaction and not all can stand to void or have penetrative sex. However, by applying the established criteria of a 2 cm macroscopic margin, the only option for these patients would have been total penectomy in at least half of the group and the remainder would have had a stump almost flush with the infra-pubic skin.

Salvage after radiotherapy and partial penectomy

The described techniques can also be used to salvage recurrences after failed radiotherapy or partial penectomy. Up to 40% of patients who receive radical radiotherapy will need surgery. Local recurrences may take several years to become apparent. In this situation, it is still possible to perform glansectomy and even corporeal resection. Surgery on these patients provides its own challenges. Irradiated tissues are brittle and are not ideal for grafting. Furthermore, it has already been mentioned in this text that there is a significant risk of deep necrosis, and therefore it is of utmost importance that tissues be handled with great care. Nevertheless, despite these potential problems the results so far have been acceptable and certainly more appealing than partial penectomy.

To improve body image and sexual function, patients who have previously undergone a partial penectomy can be offered phalloplasty. Patients with a reasonable stump and shaft skin can be lengthened by around 2–3 cm and a neoglans created. The shaft skin covering the corporeal heads is removed and replaced with a partial-thickness skin graft. The infra-pubic space is developed at the base of the penis and the penile suspensory ligaments are divided. By performing dorsal V- and Y-plasty and constructing scrotal skin flaps, enough skin can be mobilized to give the dorsal and ventral length, respectively.

Total phalloplasty

In a small number of cases, a total phallic reconstruction with a radial forearm flap can be considered. The ideal patient (who probably represents only 1–2% of referrals) would be a younger man with node negative, but extensive local disease extending into the proximal penile shaft. The procedure can be staged to occur after a subtotal penectomy, preserving the tips of the corpora and leaving adequate urethral length by creating an infrapubic rather than perineal urethrostomy. Preservation of the long saphenous veins after prophylactic groin dissection will allow a route for venous drainage. The procedure is otherwise identical to a female-to-male sex change (Ralph, personal communication).

CONCLUSIONS

The definitive treatment of penile carcinoma depends on stage. There are no randomized clinical trials

comparing the available treatment options. The majority of experts agree that stage Ta and T1, which are well or moderately differentiated carcinomas, could be treated successfully with penis preserving therapies. It is the treatment of stage T2 and low-grade T3 lesions that remains most controversial. Careful risk assessment of inherent tumor characteristics and appropriate choice of technique is necessary. A review of all patients by a multidisciplinary team familiar with the management of penile cancer is therefore important. Long-term follow-up is necessary after penile preserving therapies, as long-term recurrence rates for this technique are not known. Functionally, patients undergoing penile preserving surgical procedures do better than those having partial penectomy, and the results should be critically compared with the results of radical radiotherapy. Finally, few patients need radical penectomy, and conventional partial penectomy should only be considered if the patient is very frail.

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81 Congenital erectile curvature

Jennifer Lawson Bepple and Kurt A McCammon

INTRODUCTION

Normal erectile function is dependent on normal vascular and neurologic function as well as elasticity and compliance of all tissue layers of the penis. During tumescence, the penis fills with blood and the corporal bodies and tunica albuginea reach their limits of compliance causing rigidity. Patients with straight erections have normal and symmetric expansion of the tunica albuginea. Asymmetric expansion of one aspect of their penis causes penile curvature. This could be due to decreased compliance of one aspect of the tunica or foreshortening of one erectile body.

Penile curvature is described as either congenital or acquired. There is some confusion with the terms 'congenital curvature' and 'chordee without hypospadias'. Some use these terms interchangeably, however, we do not think they are synonymous. We reserve chordee without hypospadias for patients who have a normally placed meatus but have a ventral curvature of the penis. This curvature is associated with abnormalities of the ventral tissue planes or the corpus spongiosum. Although penile size is not 100% reliable in distinguishing between the two, patients with chordee without hypospadias usually have small penises whereas those patients with congenital curvature tend to have a larger than normal erect penis.

INCIDENCE

The true prevalence of congenital curvature is difficult to determine. There have been few studies that have attempted to determine the exact incidence of congenital curvature by excluding hypospadias patients. One reason prevalence is difficult to determine is that some patients may have curvature but do not seek medical advice because they are still able to function. Others may think this condition is normal since they have always had some degree of curvature. We have also seen many patients who have presented in their 30s or later that remained sexually inactive because of psychologic issues with their curvature and the feeling that nothing could be done to correct it. The incidence of congenital curvature of the penis is estimated to be three in 500 males.

ETIOLOGY/EMBRYOLOGY

The precise etiology of congenital curvature of the penis is unknown. During normal embryologic development, the penis goes through stages of ventral curvature and then straightens. Embryologic development of the penis is regulated by testosterone that is converted by 5-alpha-reductase to dihydrotestosterone (DHT). DHT binds to androgen receptors on all tissue layers in the penis. The individual layers of the penis may be deficient or abnormal in growth and therefore inelastic and dysgenic.

Researchers have shown that in the patient with hypospadias there is a deficiency of growth factors in the ventral skin. Whether there is a deficiency in the deeper layers of the penis is still unknown and research continues in this area. It has also been proposed that penile curvature is secondary to an arrest in normal penile development. The arrest can be due to fibrosis caused by an ingrowth of ectodermal tissue. The failure of penile development has been proposed to be a result of androgen deficiency or androgen insensitivity.

CLASSIFICATION

Devine and Horton proposed a classification system for congenital penile curvature identifying five separate types of curvature.³ Types I–III can be collectively termed chordee without hypospadias. This refers to an abnormal development of ventral penile tissue with the patient having a normally placed meatus. For patients with type I curvatures, none of the surrounding layers are normal and there is maldevelopment of the corpus spongiosum. Patients with type II curvature have a dysgenic band of fibrous tissue, which is believed to have formed from the mesenchyme that would have become Buck's and dartos fascia. This dysgenic tissue lies lateral and dorsal to the urethra, which is enclosed in the corpus spongiosum. In type III congenital curvature, the patient's urethra, corpus spongiosum, and Buck's fascia are all developed normally. The abnormality in these patients is in the dartos fascia, which has an elastic band that causes the penis to bend sharply. Not infrequently these patients have a large and prominent mons pubis.

Type IV curvature is commonly referred to as congenital curvature of the penis by the authors. In type IV penile curvature, development of the urethra, fascial layers, and corpus spongiosum is normal but there is also a relative shortness or inelastic area of the tunica albuginea. Experience with these patients has shown that they have a penis of normal length when flaccid but when erect the penis may be larger than expected. This is felt to be due to a hypercompliance of the tunica albuginea. Many of these patients will note curvature prior to puberty but this becomes more accentuated after pubescence and the penile growth spurt that occurs during adolescence.

Type V curvature is the rarest of all types and some even question whether it exists. This type is known as the congenitally short urethra. The short urethra is not elastic enough or of adequate length leading to ventral curvature during erections.

EVALUATION

All patients referred to our center undergo a complete history and physical examination, including an extensive sexual history. Complete examination is done to rule out evidence of subclinical fracture or Peyronie's disease that is obviously rare in the younger patient population.

Patients are required to supply photographs of their erect penis for documentation of the curvature. The photographs are beneficial in distinguishing between congenital curvature and chordee without hypospadias. Psychologic aspects of the disease also need to be addressed. Occasionally patients are evaluated preoperatively by a certified sex therapist and treated as needed.

Patients usually present in their late teens to early 30s. Most cannot remember their penis being straight and have always assumed their curvature was normal. After puberty and onset of sexual activity, they realize that the curvature impedes normal sexual relations. Some patients also notice that their curvature worsened with puberty. Occasionally, a patient will present after the age of 30 either having been sexually active but found it difficult functionally or psychologically, or less commonly a patient will be sexually inactive due to the curvature and the embarrassment he feels.

SURGICAL MANAGEMENT

Currently, there are no alternatives to surgery in the patient whose curvature is causing impairment of sexual function. Fortunately, most of these patients can

be corrected with a single procedure. Most patients can be straightened with incision and plication, but there are alternative procedures, including incision with grafting and penile disassembly.

Incision and plication

During correction of penile curvature, the surgeon decides between either elongating the shorter side of the erect penis via incisions and grafts or shortening the longer side with excisions or incisions and plications. Patients generally recover faster from plications compared with graft procedures. Our preference, if penile length is not a major factor, is to perform an incision and plication.

For incision and plication, a circumcising incision is made down to Buck's fascia. The penis is then degloved. An artificial erection is created with intravenous normal saline. (A tourniquet is not recommended as this may mask more proximal curvature.) A layer of dysgenic tissue, containing Buck's and dartos fascia, is often seen in patients with a ventral curvature. This inelastic fascia may be excised as the corpus spongiosum and urethra are mobilized. The urethra could be injured during mobilization of the corpus spongiosum and if this occurs, it is closed primarily. An artificial erection is recreated. If there is no more curvature, the incision is closed. Those, whose curvature is related to a differential elasticity between the dorsal and ventral aspects of the corporal bodies, may require further maneuvers to straighten the penis.

If it is determined to proceed with incision and dorsal plication, Buck's fascia is mobilized further. Care is taken to include the neurovascular structures. This may be accomplished by beginning lateral to the spongiosum and carrying the incision medial or through excision of the deep dorsal vein. After the dorsal vein is excised, the inner layer of Buck's fascia is elevated from the tunica, and then the dissection is carried lateral to the corpus spongiosum.

An artificial erection is performed and the area of maximal curvature is marked. An ellipse of tissue is marked opposite this point. One could also create two smaller ellipses opposite the point of maximal curvature. A 3-0 polypropylene suture is placed on the edges of the ellipse. An artificial erection is again performed. If the penis is straight, the suture is removed and using a scalpel, the ellipse of tunica is excised. Placing this suture prior to excision of the tunica has resulted in improved outcomes. The erectile body is not incised. A 4-0 PDS interrupted suture and 5-0 PDS running suture are used to create a watertight

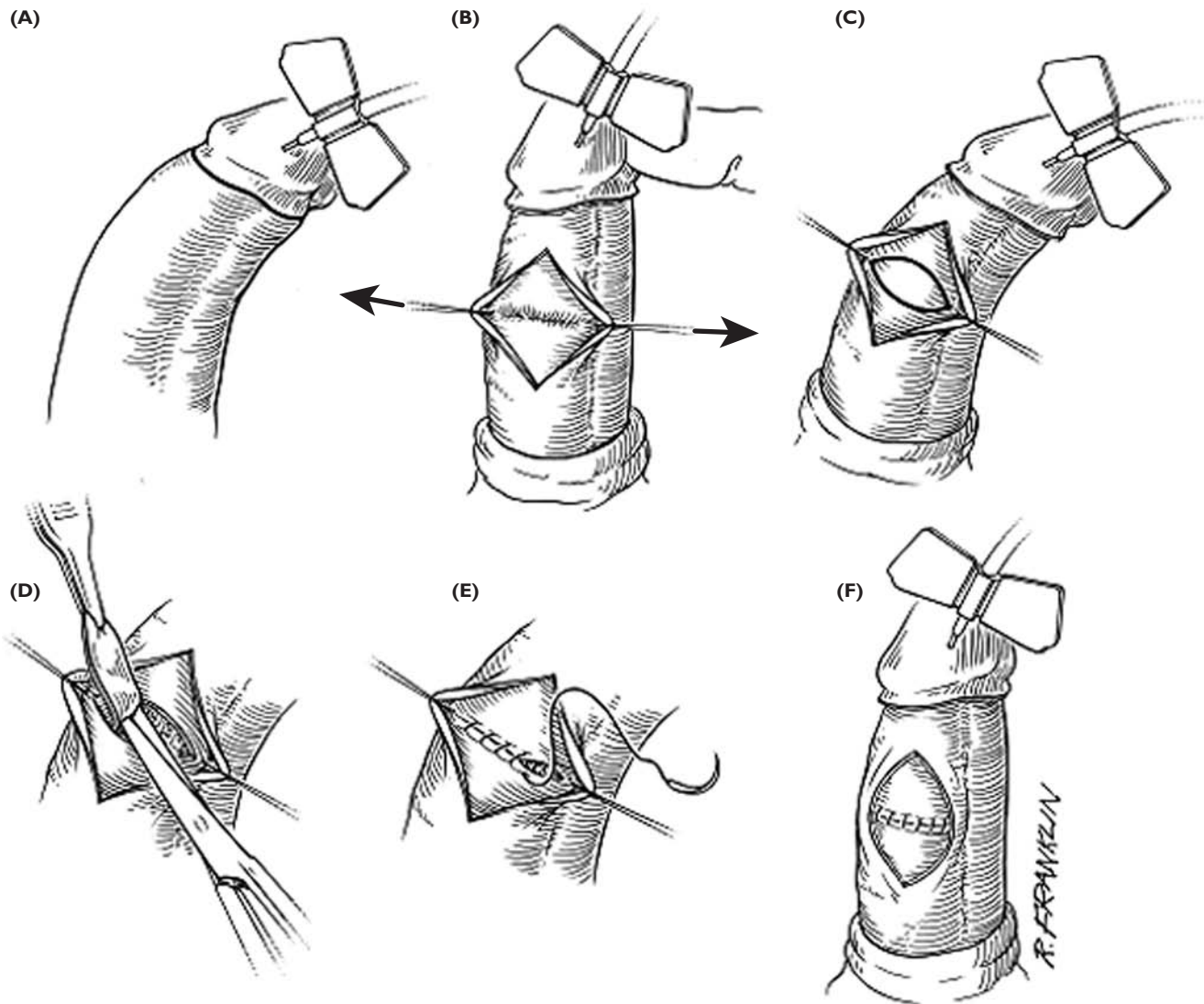


Figure 81.1 Incision and plication of congenital lateral curvature. (A) An artificial erection reveals the curvature. The incision to gain access to the potential ellipse of tissue is marked. (B) The tunica albuginea has been exposed by mobilizing Buck's fascia, and Prolene sutures have been placed at the tips of the potential ellipse. While maintaining the artificial erection, tension is established on the two sutures as the penile shaft is straightened. The fold produced in the tunica is marked. (C) When the penis is relaxed, this mark defines the ellipse of tunica to be removed. (D) The tunica is excised. (E) The edges are approximated. (F) The penis is straight. Buck's fascia and the skin are closed.

closure. It has been proposed that placing two sutures during the plication aids in preventing recurrence by providing some reinforcement of the repair during an erection but this has not been proven to be superior to the already described procedure.

Results of the incision and plication are evaluated during an artificial erection. If the repair is not adequate, further ellipses are made. If adequate, Buck's fascia is closed, two small drains are placed superficial to Buck's, and the skin is closed with a 4-0 Vicryl suture. A small Foley is placed overnight and the patient has a voiding trial in the morning. If output allows, one drain is removed in the morning on postoperative day 1 and the other may be removed later that day prior

to the patient's discharge. Outpatient surgery for congenital penile curvature has also been reported.

Patients with only lateral curvature can be managed with a small incision at the point of maximal curvature. This is identified following an artificial erection. An ellipse is made on the contralateral side at the site of maximal convexity. Similarly, 3-0 prolene sutures are placed on the edges of the ellipse and a repeat artificial erection is done. If the ellipse is adequate, the tunica is excised and the area is plicated in a similar manner as previously described (Figure 81.1).

During the case of congenital dorsal curvature, a circumcising incision is made. The corpus spongiosum is minimally mobilized. The ellipses and excisions are

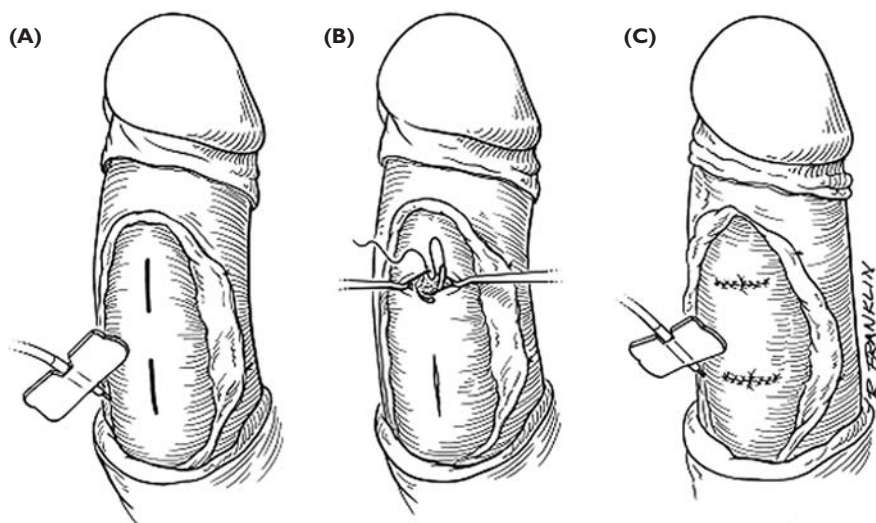


Figure 81.2 Yachia technique for correction of curvature, in this case, a patient with congenital lateral curvature. (A) Buck's fascia is reflected exposing the lateral tunica albuginea. (B) Longitudinal incisions are created at the area of maximal curvature as demonstrated by artificial erection. (C) The longitudinal closures are closed transversely, with artificial erection demonstrating good straightening of the penis.

done just lateral to the ventral midline in the corpora. The technique used is similar to that described for ventral curvature.

Yachia longitudinal plication

A circumcising incision is made and mobilization is similar to that discussed above. Yachia advocated plicating with a longitudinal incision in the tunica. These incisions are then closed transversely. The tunica is not excised (Figure 81.2).⁶

Multiple parallel plications

Similar to the Yachia plication, the multiple parallel plications do not excise tunica. A circumcising incision is made, the penis is degloved, and the deep dorsal artery and vein are identified. The neurovascular bundle is not dissected. The point of maximal curvature is identified during an artificial erection and multiple plication sutures are placed in the tunica between the deep dorsal artery and vein; 3-0 non-absorbable sutures are used (Figure 81.3). To prevent overcorrection, some sutures are not fully secured. Lateral or ventral curvature is corrected with the sutures placed more lateral, but with the same vertical orientation. For dorsal curvature, a ventral incision is made and the sutures are placed lateral to the corpus spongiosum (Figure 81.4).

Penile disassembly

This technique was described by Perovic et al to avoid penile shortening.⁵ Unfortunately, only 68% of patients report adequate straightening of their curvature. Penile

disassembly divides the penis into the glans and neurovascular bundle dorsally, the urethra ventrally, and the corporeal bodies.

Chordee without hypospadias

Chordee without hypospadias is related to a defect in the ventral aspect of the corporeal bodies. This dysgenetic tissue can be excised as discussed earlier. If this does not result in straightening during an artificial erection, a small incision can be made on the ventral midline aspect of the corporal bodies. This allows the tunica to move laterally, resulting in straightening. The erectile tissue should not be entered. If this is unsuccessful, the neurovascular structures are again mobilized to excise an ellipse of tunica on the dorsal aspect of the corpora, as described previously.

A graft is another option for this patient population. It may be helpful in those with severe chordee or those with a smaller than average penis. The advantage of a graft is that it does not cause shortening of the penis. However, it does have a risk of veno-occlusive dysfunction. This has been shown in the Peyronie's population. However, it may be less of a risk in the pediatric patient because the graft required is smaller and the tunica is not excised.

OUTCOMES

Surgical correction of congenital penile curvature is reported to be more than 85% successful with similarly high rates of patient satisfaction. Risks associated with correction include penile shortening, suture granuloma, penile irregularity, pain at the site of plication, and

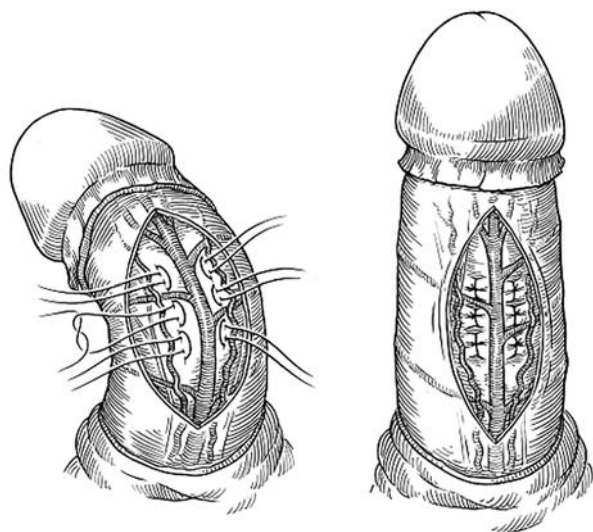


Figure 81.3 Multiple parallel plications. The deep dorsal artery and vein are identified after degloving the penis and mobilizing Buck's fascia. Multiple plication sutures are placed after an artificial erection; 3-0 non-absorbable sutures are placed in the tunica between the deep dorsal artery and vein.

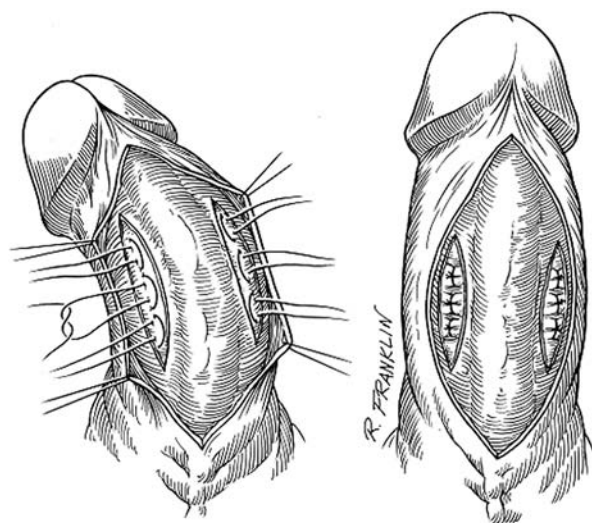


Figure 81.4 Multiple parallel plications for dorsal curvature. A ventral incision is made and 3-0 non-absorbable sutures are placed lateral to the corpus spongiosum in a vertical orientation.

temporary loss of glans sensation. Erectile dysfunction is a very rare complication. There is one reported case of penile necrosis, thought to be secondary to the use of a tourniquet, which we do not advocate.

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82 Peyronie's disease: Corporoplasty and plication procedures

Kenneth W Angermeier

PEYRONIE'S DISEASE

Peyronie's disease is characterized by the development of fibrosis within the tunica albuginea of the corpora cavernosa. This scar or plaque restricts the elasticity of the involved tunical segment and may lead to erectile curvature. The most accepted etiology of Peyronie's disease to date is that repetitive penile trauma is responsible for the tunical injury. During erection, the penis remains relatively straight as the elastic corpora cavernosa fill with blood. The septal strands become taut between the dorsal and ventral tunica albuginea, contributing to the axial rigidity of the penis. When the erect penis is subjected to loading and some degree of bending occurs, stress is focused at the junction of the septal strands and tunica albuginea.¹ Bending of the penis during intercourse may be exaggerated by age-related changes in erectile function and rigidity. In addition, it has been shown that the concentration of elastic fibers within the tunica albuginea decreases with time.² It has been postulated that a combination of these factors may lead to delamination of the inner circular and outer longitudinal layers of the tunica albuginea at the site of attachment of the septal strands, resulting in hemorrhage and local inflammation. Fibrin may become trapped within the hypovascular tunica, leading to persistent inflammation and subsequent fibrosis.¹ The process can extend laterally, leading to a more extensive or even circumferential plaque. Obviously the initial aspects of this process occur in many men, more than those with clinical Peyronie's disease, indicating that some inherent predisposition to excessive scar formation may exist.

Although some patients with Peyronie's disease may recall a distinct episode of buckling trauma to the penis during intercourse, most do not. The disease process begins with an inflammatory phase, which may be associated with pain and tunical induration. Over a period of 12–24 months, the tunical lesion remodels and matures, with resolution of discomfort in the majority of cases. Variable degrees of erectile curvature may occur as a result of this process, and may change over time. Once the scar has matured, there will be no further change in the configuration of the penis.³ Erectile

curvature is due to corporeal tethering by the fibrotic tunica and is in the direction of the most predominant lesion. Opposing plaques may balance each other such that the erect penis is relatively straight, although often foreshortened. Corporeal flaccidity distal to the level of the plaque may be present in some patients as well. The exact cause of this disparity in erectile rigidity is unclear, as Doppler studies have shown that distal intracavernosal arterial flow is usually maintained. Restriction of full expansion of the tunica albuginea and the intracavernosal fibrous network may mechanically limit erectile rigidity, or possibly contribute to localized corporeal veno-occlusive dysfunction.⁴

Evaluation of the patient with Peyronie's disease begins with a detailed history. It is important to accurately document the onset of initial symptoms and the evolution of those symptoms over time. Patients may present with penile pain during erection, or palpate a nodule or firmness along the penile shaft. Others describe the presence of curvature as their initial evidence of disease. Patients should be asked whether an episode of penile buckling or trauma preceded the condition. When present, pain will eventually resolve in most cases as inflammation subsides. Configuration and stability of the erect penis is documented by history and with the aid of photographs.

A detailed sexual history is also important, as erectile function is a critical factor in determining the most appropriate form of treatment. Patients are asked about their sexual function prior to and following the onset of disease. We record the frequency of intercourse, erectile rigidity and maintenance, and the integrity of orgasm, ejaculation, and libido. The presence and nature of any curvature prior to the development of Peyronie's disease is documented.

Physical examination involves grasping the glans and stretching the penis, to allow for accurate palpation between the index finger and thumb. The extent and location of the plaque is defined including dorsal, lateral, and ventral components when present. Imaging studies do not seem to contribute significant clinically relevant information in our experience.

After complete maturation of the tunical scar, patients with mild to moderate curvature who remain

functional should be followed conservatively. If erectile rigidity or maintenance is a problem, they can be managed with standard treatments for impotence such as an oral agent, vacuum erection device, urethral suppository, injection therapy, or a penile prosthesis. In patients with erectile curvature precluding or significantly interfering with sexual intercourse, surgical treatment is considered. Erectile curvature tends to become problematic when it exceeds 45° dorsally, or 30° laterally or ventrally. To confirm stability of the disease prior to surgery, we wait until the disease has been present for at least 1 year and erectile configuration stable for at least 6 months before proceeding. Selected patients undergo a duplex ultrasound of the penis following pharmacologic injection prior to surgery. The ultrasound allows one to obtain information with regard to cavernosal arterial inflow and veno-occlusion, and provides an opportunity to visualize the erectile configuration if photographs are not available. In addition, the presence of any collateral vessels from the dorsal artery of the penis to the cavernosal arterial system is documented, as these may be compromised if the neurovascular bundles require mobilization at the time of repair.

There are two ways to surgically straighten a curved erection: shorten the long side of the penis (tunical corporoplasty or plication), or lengthen the short side (tunical incision/excision with grafting). In patients with Peyronie's disease, there are several factors that we take into consideration when counseling patients about selecting a surgical procedure.

Erectile function

Postoperative erectile dysfunction has been observed in approximately 10–30% of patients following plaque incision or excision with grafting.^{5–7} In a group of patients assessed by dynamic infusion cavernosometry prior to surgery, it was shown that there is a correlation between preoperative erectile function and postoperative success following plaque excision and dermal graft inlay.⁶ Preoperative evaluation of erectile function with nocturnal penile tumescence (NPT) monitoring or duplex ultrasonography has also been reported in patients undergoing plaque incision using dermis or alternative grafts. These studies suggest that postoperative results are optimal in patients with normal subjective and objective erectile function preoperatively.^{7–9} Based upon this information, patients with below normal but adequate erectile function with or without a phosphodiesterase inhibitor may wish to consider corporoplasty or plication as long as other factors are

favorable. With these procedures, there is less disruption of the erectile tissue and subtunical venous network. The risk of deterioration of erectile rigidity at our institution has been very low, and this is consistent with other reports using similar techniques.^{10–12}

Penile length

Corporoplasty and plication procedures result in further shortening of erect penile length, as the longer side of the penis is shortened to match the opposite side. Although this provides excellent penile straightening, some additional decrease in erectile length occurs. This must be clearly explained to the patient prior to surgery. Patients with greater baseline penile length are less likely to be functionally affected by this. One can estimate the length of the erection postoperatively by manually stretching the penis in the flaccid state, as the stretched length is limited by the short side. This stretched penile length should be demonstrated to the patient. Plaque incision or excision with graft inlay tends to preserve remaining length by expanding the 'short' aspect of the penis for straightening. Patients should be cautioned, however, that erectile length will not be fully restored in most cases to their premorbid status, even following plaque incision or excision.

Degree of curvature

If curvature is severe, tunical corporoplasty or plication will need to be more extensive and may result in excessive penile shortening. Therefore, plaque incision or excision may be preferred in this situation.

Location of curvature

In the setting of dorsal curvature, plaque incision and grafting requires mobilization of the neurovascular bundles to expose the tunical scar. In experienced hands, this can be readily and safely accomplished. However, this maneuver may result in a temporary change in sensation of the glans penis. Ventral curvature necessitates mobilization of the corpus spongiosum, which carries a low risk of urethral injury. Depending on the technique, tunical corporoplasty or plication generally requires less manipulation of the neurovascular bundles to correct ventral curvature. Correction of dorsal or lateral curvature requires no special maneuvers relative to the neurovascular bundles or urethra.

This decreases operative time and lessens the chance of alterations in glans sensation postoperatively.

Local erectile deformity

Patients with Peyronie's disease may develop significant constriction or indentation of the penis at the site of the tunical scar. Tunical corporoplasty or plication will generally not change the appearance of this lesion despite penile straightening. If the plication results in mild indentation of the tunica albuginea opposite the scar deformity, there could possibly be some instability or hinging of the erection in this area. In this setting, therefore, a graft procedure may be preferred in order to correct a severe local constriction deformity.

CORPOROPLASTY AND PLICATION PROCEDURES

Tunical excision

The original technique described by Nesbit¹³ begins most commonly by degloving the penis through a circumcising incision. Prior to any penile procedure, it is important to discuss circumcision status with the patient to make sure that it is clear what will be done in this regard at the time of surgery. If an uncircumcised patient wishes to avoid circumcision, the ventrum of the penis can be approached through a ventral midline incision or a lateral curvature may be corrected using a lateral longitudinal incision. For dorsal exposure, a sigmoid incision is preferred to minimize scar contracture. After the penis is exposed, an artificial erection is performed to assess the curvature and plan the site for tunical excision. Buck's fascia is incised longitudinally just above the level of the corpus spongiosum and elevated at the appropriate location opposite the site of maximal curvature. Large circumflex veins should be ligated and divided between 4-0 Vicryl ties with control of smaller vessels using bipolar cautery. In the setting of lateral or dorsal curvature, this part of the procedure is relatively straightforward as the dorsal neurovascular bundles do not require extensive mobilization. For ventral curvature, however, these structures are elevated by dissecting in the plane between the tunica albuginea and Buck's fascia beginning ventrolaterally and working toward the midline. This is done very meticulously, using loupe magnification and bipolar cautery for hemostasis. Nesbit did not carry this dissection across the midline, but far

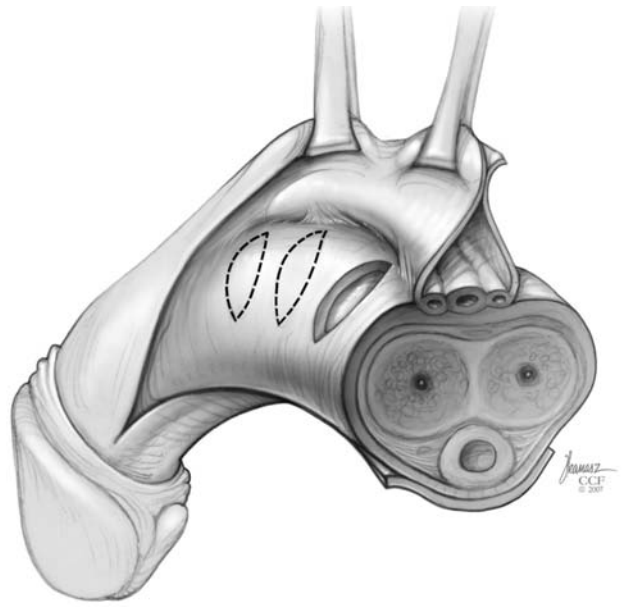


Figure 82.1 Nesbit procedure for correction of ventral curvature: partial mobilization of neurovascular bundles with tunical ellipses marked for excision. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

enough to expose the dorsolateral aspects of the corpora cavernosa (Figure 82.1). For most corporoplasty or plication procedures, once the tunica albuginea in the area of interest is exposed, I generally prefer to simulate the plication first using Allis clamps on the tunica albuginea. An artificial erection is performed and the clamps can be adjusted to get the desired effect. The marks of the clamps on the tunica are then used as a guide to excise transversely oriented ellipses of tunica, taking great care to preserve the underlying erectile tissue. In the setting of lateral curvature, one column of ellipses is usually sufficient. For dorsal or ventral curvature, paired ellipses on either side of the midline are used. The elliptical defects are then closed transversely, effectively shortening the long side of the penis (Figure 82.2). A variety of sutures have been used in the past to close these defects. The options include a 2-0 or 3-0 non-absorbable monofilament, 3-0 PDS, or a combination of these with the knots buried. The artificial erection is repeated and additional ellipses can be added as needed until adequate straightening is obtained. Two to three pairs of ellipses are usually sufficient. Buck's fascia is approximated over the plication sites using interrupted absorbable 5-0 sutures. A small suction drain may be placed in the subdartos space as needed. The dartos layer and skin are closed in standard fashion.

Pryor and Fitzpatrick¹⁴ reported their modification of Nesbit's procedure in 1979. They advocated the

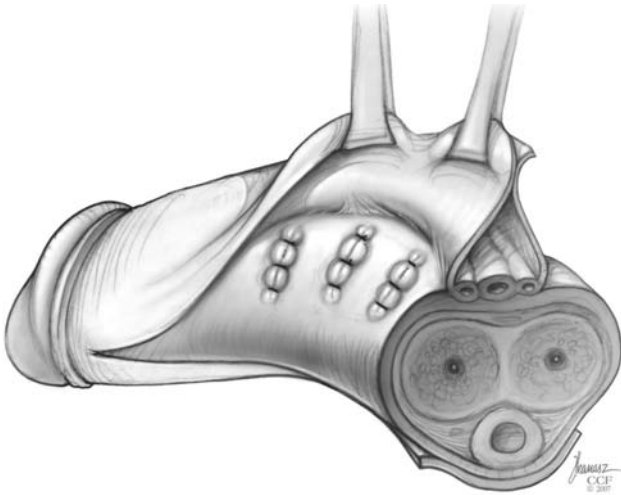


Figure 82.2 Transverse closure of elliptical tunical defects. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

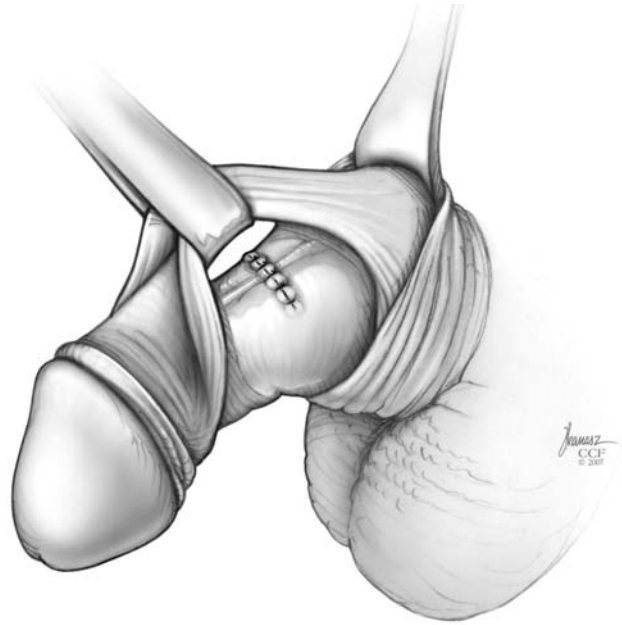


Figure 82.4 Transverse closure of tunical defect. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

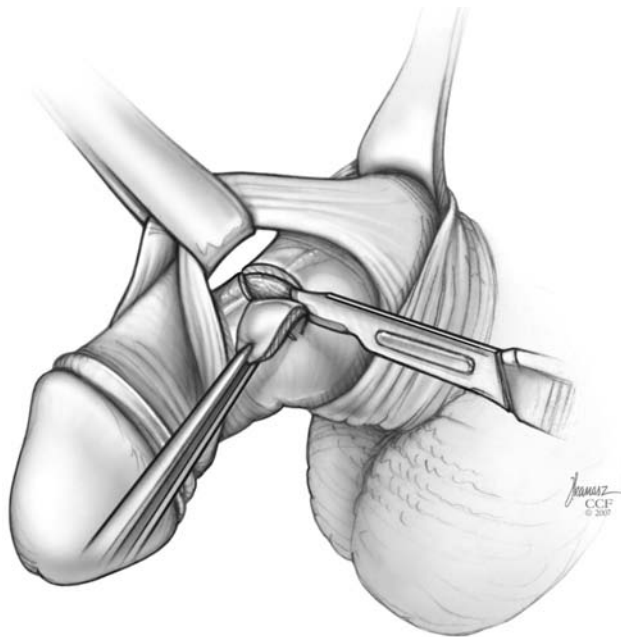


Figure 82.3 Complete mobilization of neurovascular bundles with excision of single tunical ellipse at point of maximal curvature. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

excision of a single tunical ellipse opposite the point of maximum curvature. The tunica albuginea is exposed with complete mobilization of the neurovascular bundles when necessary depending on the direction of curvature (Figure 82.3). This can be done through a lateral approach or in my experience more commonly using a dorsal approach through the bed of the dorsal vein of the penis. Planning of the ellipse may be aided by using interrupted sutures to imbricate the tunica

and assess straightening, or with the use of Allis clamps. The edges of the ellipse are marked and used as a guide for excision after the sutures or clamps are removed. The ellipse is generally 0.5–1 cm in width. The resulting defect is closed transversely (Figure 82.4). When excising an ellipse, I prefer to close the tunica with one to three evenly spaced interrupted sutures of 2-0 Prolene with the knots buried, with final closure using a running 3-0 PDS. Although applicable to a variety of deformities, I primarily use this technique for patients with ventral curvature.

Tunical incision

In 1973, Saalfeld et al¹⁵ described a patient with congenital ventral curvature who underwent repair with two longitudinal dorsal tunical incisions which were then closed transversely. This allowed shortening of the longer aspect of the corpora cavernosa without tissue excision. I have used a similar technique described by Yachia,¹⁶ who combined the use of Allis clamps with transverse closure of longitudinal tunical incisions. In this technique, the penis is degloved and artificial erection performed as described above. After marking the site of maximal curvature, the tunical albuginea at the corporotomy site is exposed by elevating Buck's fascia. This can be done focally at each planned incision site, but I prefer a single longitudinal incision and subsequent

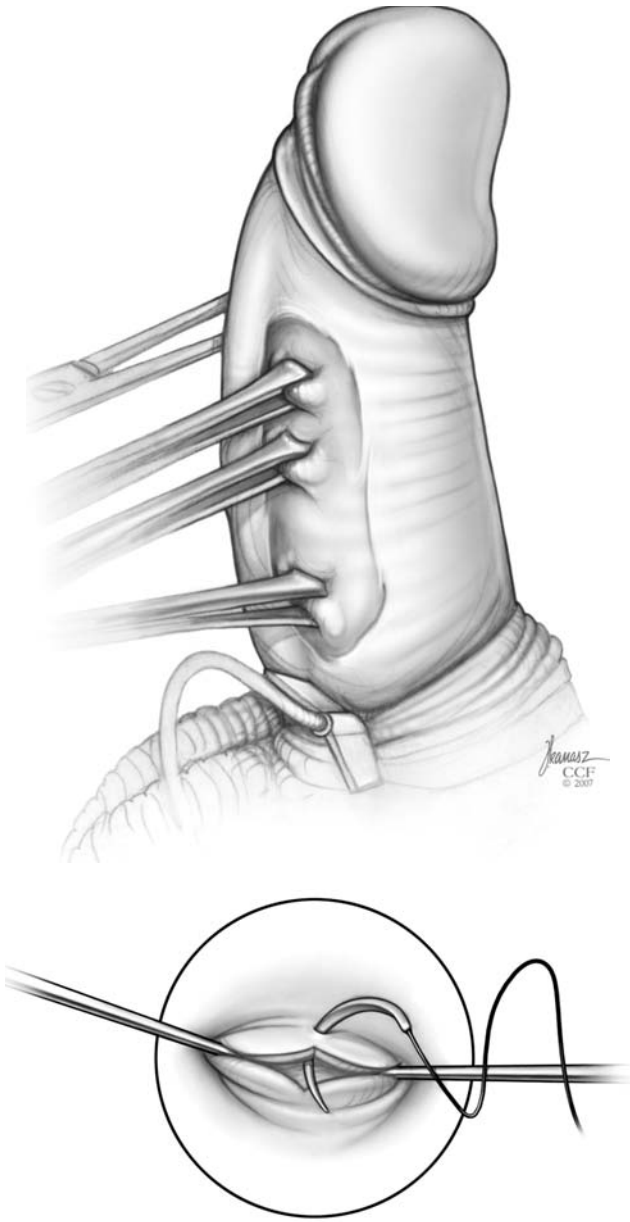


Figure 82.5 Yachia corporoplasty: Allis clamps applied to exposed tunica albuginea ventrally simulate correction of dorsal erectile curvature; Inset: transverse closure of longitudinal tunical incision at each site. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

dissection of Buck's fascia for improved tunical exposure during correction of dorsal and lateral curvature. Allis clamps are then applied to the tunica albuginea to simulate the plication, in either a single column for lateral curvature or paired columns on each side of the midline for dorsal curvature (Figure 82.5). After the clamps have been adjusted to obtain adequate straightening as documented by artificial erection, the first clamp is removed and the tunica albuginea is incised longitudinally between the marks of the clamp using a

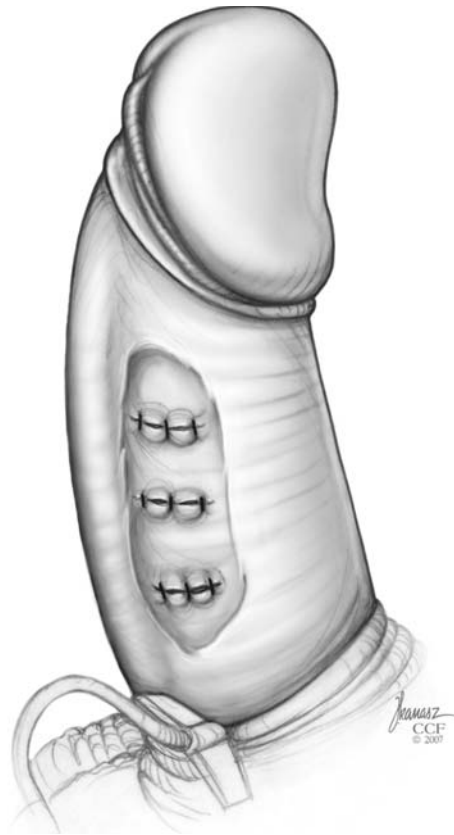


Figure 82.6 Yachia corporoplasty: final tunical closure. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

no. 11 scalpel blade. Care is taken not to incise into the underlying erectile tissue. Single skin hooks are used to draw the incision transversely (Figure 82.5). The tunical defect is closed with an interrupted suture of 3-0 Prolene with the knot buried at the midpoint of the incision, followed by final closure using running 3-0 PDS (Figure 82.6). This is repeated at each corporotomy site, and the final result is assessed with repeat artificial erection. This is currently my favored approach for correction of dorsal and lateral curvature and it has provided excellent results.¹⁷

No tunical incision

In 1985 Essed and Schroeder¹⁸ reported a technique for suture plication of the tunica albuginea without excision or incision. They felt that this eliminated unnecessary corporeal trauma and avoided damage to underlying erectile tissue. In the setting of dorsal curvature, the urethra is circumferentially mobilized off the corpora cavernosa to expose their ventral aspect (see Figure 82.8). Alternatively, the neurovascular bundles within Buck's fascia are dissected off the dorsal tunica

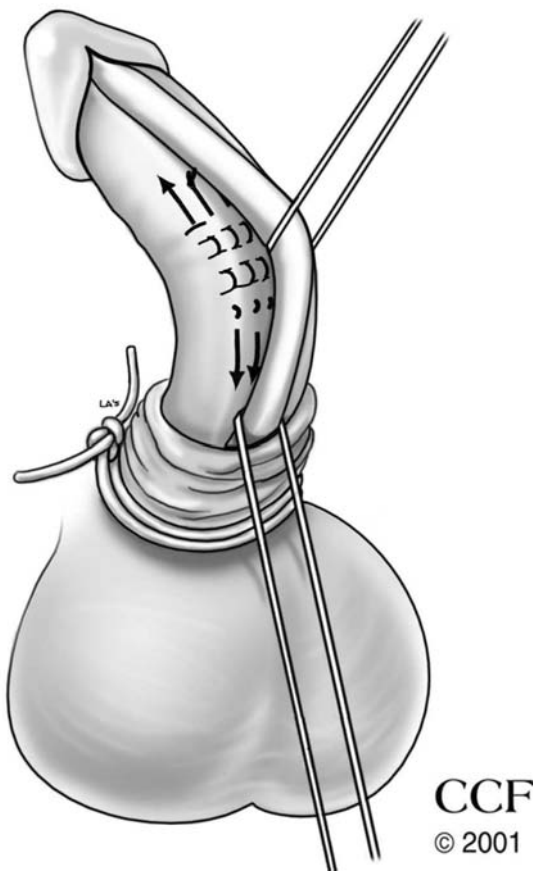


Figure 82.7 Essed-Schroeder tunical plication: mobilization of urethra and placement of plicating sutures for correction of dorsal curvature. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

albuginea to treat ventral curvature. Two or four single skin hooks are inserted into the tunica and pulled cross-wise to simulate the plication. When straightening is achieved using the hooks, the points of insertion are marked and then connected. This usually results in a marked ellipse opposite the tunical scar. Non-absorbable 3-0 multifilament sutures are placed to approximate the marked tunica albuginea (Figure 82.7). This maneuver results in shortening of the convex side of the penis and overall straightening. Multiple sutures are usually required (Figure 82.8). Knispel et al¹⁹ modified this procedure slightly by using interrupted sutures of 2-0 Prolene with the knots inverted, resulting in a lower incidence of palpable knots.

In 1992, Donatucci and Lue²⁰ described a procedure for suture plication that obviates the need for mobilization of the neurovascular bundles or the corpus spongiosum. After the induction of anesthesia, an intracavernosal injection of papaverine or alprostadil is given. Depending upon the direction of curvature, the corpora may be exposed through a lateral, ventral, or

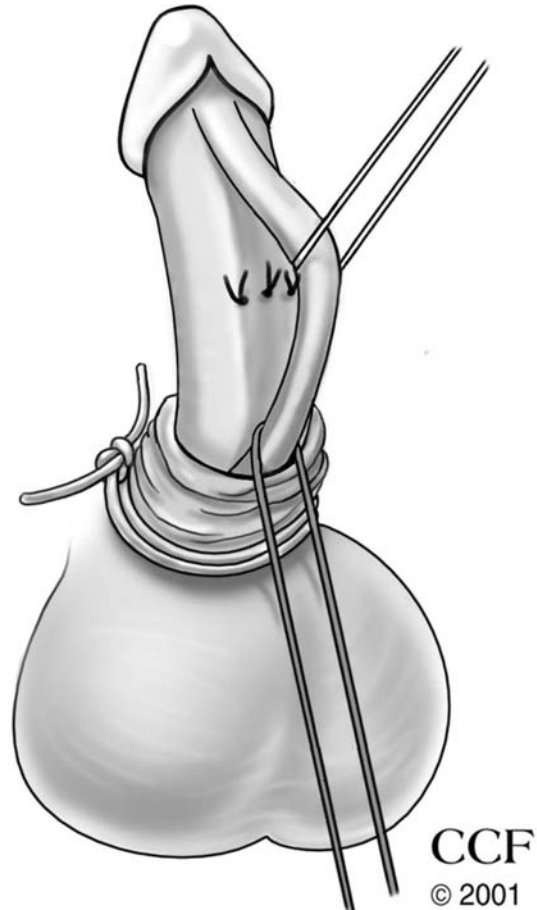


Figure 82.8 Plicating sutures tied securely. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

circumcising incision. After the site opposite the area of maximal curvature is exposed, the proposed suture entry sites are marked with a pen. Two or three pairs of 2-0 Ticron or Tevdex plicating sutures are used in order to minimize suture tension and postoperative discomfort. In the setting of ventral curvature, the sutures are placed into the tunica albuginea between the dorsal vein and the dorsal arteries (Figure 82.10). In order to correct dorsal curvature, they are perispongiosal in location (Figure 82.10). The sutures are tied one row at a time and the degree of correction can be continuously monitored as a result of the pharmacologic erection. After penile straightening, the erection is reversed using intracavernosal phenylephrine if necessary.

POSTOPERATIVE CARE

Postoperative care following the above procedures varies, but some generalizations can be made. The majority of procedures are done on an outpatient basis, although

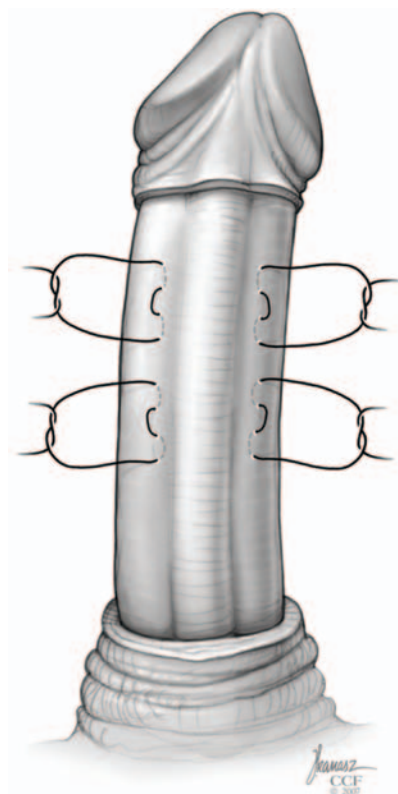


Figure 82.9 Suture plication described by Lue and Donatucci: correction of dorsal curvature. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

patients undergoing complete mobilization of the neurovascular bundles may at times be kept overnight for 23-hour observation. In these patients, a Foley catheter is inserted and removed the next morning and a small suction drain is placed in the subdartos space with removal at the same time as the catheter. We use a clear adhesive dressing which the patient is instructed to remove in the shower 4–5 days following surgery. Painful erections can be minimized with the use of diazepam at bedtime and amyl nitrite capsules as needed for the first 7–10 days. Sexual intercourse is allowed at approximately 6 weeks postoperatively, as this is when sufficient healing has generally occurred with resolution of pain and edema.

RESULTS

Kadioglu et al²¹ recently reviewed the literature and documented reported outcomes in previous studies on plication procedures. Excisional and incisional procedures resulted in similar rates of penile straightening and patient satisfaction, approximately 75–100% and 65–100%, respectively. Postoperative erectile

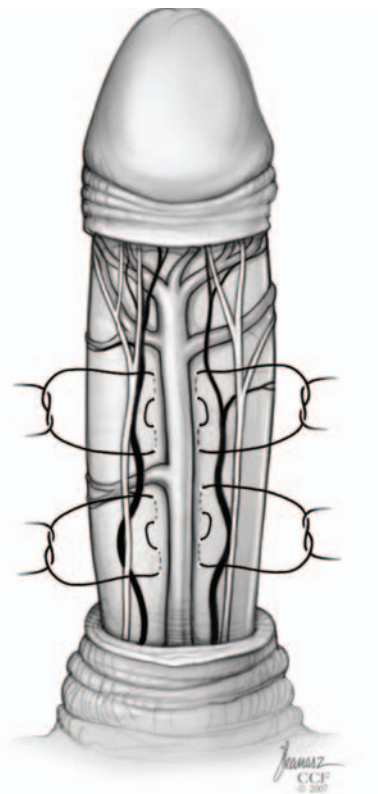


Figure 82.10 Suture placement for correction of ventral curvature. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

dysfunction (ED) initially appears to be a little lower in the incisional group ranging from 0 to 7.6% as opposed to 4–11.5% in the excisional group. However, the outlier of 11.5% in the excisional group included ED occurring over a long period of follow-up, and may represent the natural history of the disease as opposed to an issue related to the operative procedure.²² Therefore, the rates of postoperative ED are probably quite similar. Patients undergoing suture plication were noted to have results that varied considerably, experiencing postoperative straightening in 57–91%, satisfaction in 62–96%, and ED in 6–38%. The largest series of 124 patients reported penile straightening in 85% and postoperative ED in 6% and may more accurately reflect contemporary results.²³

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83 Surgery for Peyronie's disease: dermal graft techniques

Gerald H Jordan and Ramon Virasoro

Many urologists tend to refer to any acquired curvature of the penis as Peyronie's disease. The authors prefer to limit the diagnosis to those acquired curvatures that are due to trauma to the insertion of the midline septal fibers. Thus, in the authors' opinion, all true Peyronie's disease, and all true Peyronie's plaques, involve either the dorsal insertion and/or the ventral insertion of the septal fibers. The anatomy of the penis is depicted in Figure 83.1. In the location of the dorsal insertion, the tunica albuginea is bilaminar. The septal fibers interweave with the inner lamina of the tunica albuginea, the outer longitudinal lamina, being truly a laminate, has no true fibrous connection to the septal fibers.

The outer longitudinal lamina attenuates in the ventral midline. At the area of the periurethral ridges, the tunica albuginea is quite thick. However, in the midline of the ventrum, the midline septal fibers interweave with the inner circular lamina, and, at that location, it is the only lamina. This fact of the architecture is felt to be one of the entities that could explain why most Peyronie's disease is associated with dorsal curvature and dorsal plaques.

It is not unusual in patients with dorsal curvature to feel scarring in the ventrum of the corpora cavernosa; although most Peyronie's patients will have either dorsal curvature or complex dorsal curvature. However, those patients with ventral curvature, since Lowsley's article,^{1,2} have declared themselves as having 'a different disease'. Patients with ventral Peyronie's disease do not do well, in the authors' opinion, and in the opinion of many others, with grafting techniques.

While Peyronie's disease is not life threatening, corrective surgery for Peyronie's disease is felt often to be 'life saving' by some patients. The emotional effects on the couple afflicted with Peyronie's disease cannot be underestimated. Jones discussed the counseling of a patient with Peyronie's disease, and likened it to counseling an individual following the death of a loved one.³ He, however, added that these patients, in addition to having all of the factors associated with grief, have a poor self-image and feelings of self-disgust. Recent development of a validated questionnaire surrounding Peyronie's disease and its effects substantiate Jones' initial premises.

A number of studies have suggested that the vast majority of patients with Peyronie's disease have an element of erectile dysfunction (ED). Certainly, in the author's experience, that background of ED must always be kept in mind. Because of that, at this center, all patients are very carefully stratified by testing the vascular parameters of their erectile function. This testing involves the use of duplex ultrasound and, selectively, dynamic infusion pharmacocavernosometry/ cavernosography. In an analysis undertaken at our institution, we found that the factor that most influenced the results of grafting operations for Peyronie's disease was the existence preoperatively of cavernous veno-occlusive dysfunction. Even the slightest amount preoperatively, diminished the prognosis for a good result. At our institution, we define a good result as the curvature has been corrected so that any residual curvature does not interfere with intercourse, and erectile function is preserved at the level that it was preoperatively. Achieving this goal is relatively difficult, and almost impossible in the patient with preoperative veno-occlusive dysfunction. A patient is a surgical candidate when the disease is in the quiescent phase, when the curvature causes significant disability with regards to intercourse, and when the patient is motivated to proceed with surgery. It is imperative that the patient understands that all of our surgeries are designed to create an adequate penis for intercourse. There is no way for us to restore lost length, often we cannot correct all indentations; also, as mentioned, in the very definition of a good result, the promise of a perfectly straight penis cannot always be met either.

There is no best operation for all patients with Peyronie's disease. Certainly plication or corporoplasty techniques rightfully occupy a prominent role amongst surgeries for Peyronie's disease. Generically speaking, these surgeries can be lumped together under the category of those that shorten the lesser involved aspect of the corpora cavernosa.

On the other extreme, those surgeries which lengthen the shorter aspect of the corpora cavernosa all require grafts, as they are associated with either incision or excision of the scarring responsible for the deformity. The defect in the tunica albuginea is then dealt with using a graft inlay type technique.

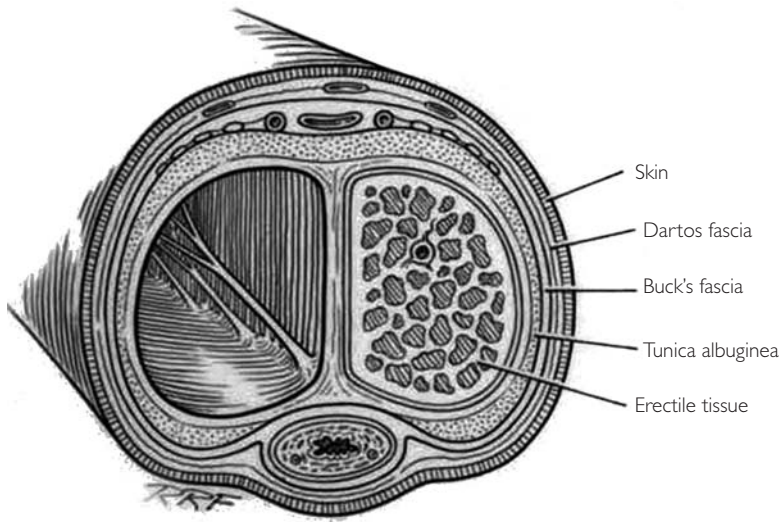


Figure 83.1 Illustration of the cross-section of the penis. Note that throughout most of the circumference, the tunica albuginea of the corpora cavernosa is bilaminar. The outer longitudinal lamina, however, attenuates in the ventral midline. Also note that the thickness of the tunica albuginea of the corpora cavernosa is thickest at the dorsum and at the periurethral area bilaterally ventrally. Note that the dartos fascia surrounds the dorsal neurovascular structures in envelope fashion, and surrounds the corpus spongiosum in envelope fashion.

A number of grafts have been used historically. The first grafts to be used were fat grafts, described by Lowsley in 1943.² In 1973, Bystrom reported the use of dermal fat grafts.⁴ In that same year, Devine and Horton described the use of dermal grafts.⁵ Sachse described the use of vein grafts in 1976,⁶ but clearly the use of vein grafts was popularized by Lue's reintroduction of them in the late 1990s.^{7,8} Kelami suggested the use of dura,⁹ while Bruschini and Mitre suggested the use of rectus fascia.¹⁰ Ho described the use of Dacron in 1982.¹¹ Both Amin and Das in separate papers described the use of tunica vaginalis.^{12,13} Parsons suggested the use of Gortex® (W.L. Gore & Associates).¹⁴ Hellstrom used silastic sheaths¹⁵ and Gelbard used the temporalis fascia as a graft in 1991.¹⁶ Indeed the temporalis fascia was also proposed by Bunkey, who proposed using the fascia as a 'microvascular free' transfer.¹⁷ Hellstrom in 2000 suggested the use of pericardium,¹⁸ Knoll reported a series using the SurgiSIS Biodesign® (Cook Biotech Inc, West Lafayette, IN, USA) Biotech® (Cook Urological, West Lafayette, IN) graft in 2003, and InteXën LP™ (American Medical Systems, Minnetonka, Minnesota) is under investigation as another off-the-shelf graft.^{19,20} The grafts, however, that have stood the test of time are the dermal graft, the vein graft, the temporalis fascia graft, pericardium, and perhaps small intestinal submucosa (SIS). Gortex and Dacron continue to be used, but usually associated with the implantation of a penile prosthesis.

Devine and Horton suggested the aggressive resection of all of the offending Peyronie's plaque.²¹ Thus very large corporotomy defects were created. Schreiter, in work that was never published, sought to define factors associated with subsequent problems with erections.²² He found that the larger the corporotomy defect, i.e. the larger the dermal graft, the higher the chance of

postoperative problems with erectile function. This fact, along with noticing that wide resection of plaques was not necessary in most cases, led to a more aggressive use of incision techniques.²³ Gelbard was one of the first to aggressively pursue incision techniques. However, he used multiple incisions, feeling that by doing so, a 'smoother' correction of the curvature was achieved.^{7,8} As Lue started using vein grafts more aggressively, he evolved a technique of creating a single aggressive incision at the point of maximal curvature. The technique has been variably modified, but represents the basis of the technique that the authors currently use when employing graft techniques for the correction of curvature associated with Peyronie's disease. The authors recommend against the use of graft techniques for patients with ventral curvature. Thus in most cases, the deep structures of the penis are accessed by creating an incision through the patient's prior circumcision scar. In the case of those patients who are not circumcised, circumcision is suggested. If, however, the patient does not accept circumcision then an incision is created as would be done for a sleeve circumcision, leaving a short preputial cuff below the coronal margin. The incision is then carried sharply down to the superficial lamina of the Buck's fascia. The penis is degloved in that layer. The dorsal structures are exposed. The superficial lamina of Buck's fascia is opened over the path of the deep dorsal vein. The dorsal vein is then excised from approximately the penopubic junction to the retrocoronal plexus. The junctures with the circumferential veins are either cauterized, or ligated. The deep lamina of Buck's fascia is then opened in the midline, exposing the tunica albuginea.

The dorsoneurovascular structures are elevated in concert with both lamina of Buck's fascia. The Buck's fascia is elevated off the plaque, to the point of normal

tissue proximally and distally, and to the ventral aspect of the penis laterally. This aggressive elevation of the dorsoneurovascular structures seems to limit the neuropraxias that can be seen with stretching the structures. By aggressively elevating the Buck's fascia and the dorsoneurovascular structures, the dorsoneurovascular structures seem to be less traumatized by stretch, with less early neurapraxia being noted. In those plaques that extend towards the coronal margin, the dissection is carried distally on the layer of the tunica albuginea beneath the coronal margin and beneath the glans. The dissection can be carried to the tips of the corpora if required. Once normal tunica albuginea has been exposed, both proximally and distally, and wide exposure of the ventral lateral aspect of the corpora cavernosa has been achieved tacking sutures are placed.

An artificial erection is performed, and the point of maximal curvature is marked with a suture. At that point, a narrow strip of tunica albuginea is marked extending from the lateral aspect of one corpora to the lateral aspect of the other corpora (Figure 83.2). Then longitudinal incisions are created roughly at the lateral margin of the corpora cavernosa. The resulting incision is the shape of an H with the midline strip being a rather broad transverse member. The tunica albuginea is then incised through these carefully marked areas. What results are flaps of the tunica albuginea which are elevated off the thickened midline septal fibers (Figure 83.3). All of the thickened midline septal fibers are released, the dorsal tunica albuginea is released to the point that the septal fibers become normal. This maneuver is felt to be extremely important if one is to achieve adequate straightening. The midline strip is excised (Figure 83.4). Previous to the application of this technique, a simple H incision was used. No strip was excised. Using that technique, the penis was effectively straightened in about 70% of patients. 'Touch-up plications' were thus employed in about 30% of patients. However, with the addition of the excision of the small midline strip, only the rare patient will require touch-up plication. In general, this is for persistent 'tilt of the glans'. Once the incisions have been created and the flaps elevated, the H flaps are allowed to slide. The grafts are then sutured in place. The resulting corporotomy defect is then replaced with a graft. As mentioned, dermis can be used (Figure 83.5), vein can be used (Figure 83.6), or one of the inert collagen matrix grafts can be used. While the inert collagen matrices are termed grafts, it must be recognized that indeed they are not grafts in the truest sense of the definition. The precise mechanism by which these inert collagen matrices work has not been accurately determined.

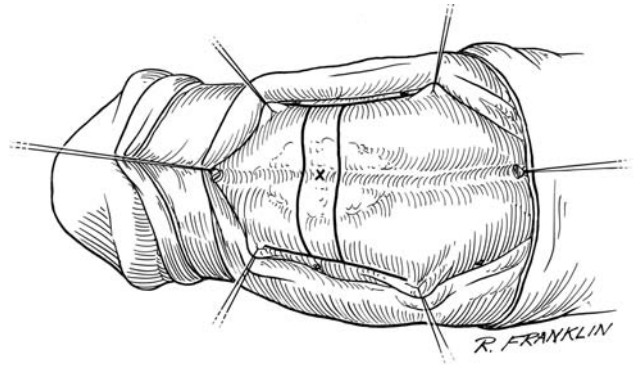


Figure 83.2 Illustration of the 'sliding H' technique of incision of a Peyronie's plaque. The X marks the point of maximal curvature, a narrow strip of tunica albuginea is marked on either side of that midline point, extending laterally where longitudinal incisions are created bilaterally.

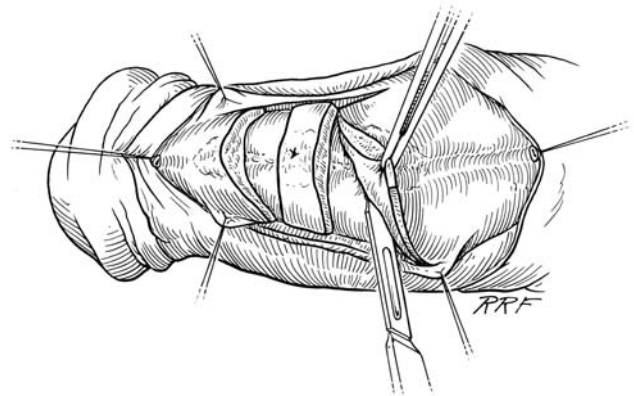


Figure 83.3 The incisions are created, the flaps of the H are elevated, the thickened midline fibers are divided, and the flaps are elevated to the point that the midline fibers become normal.

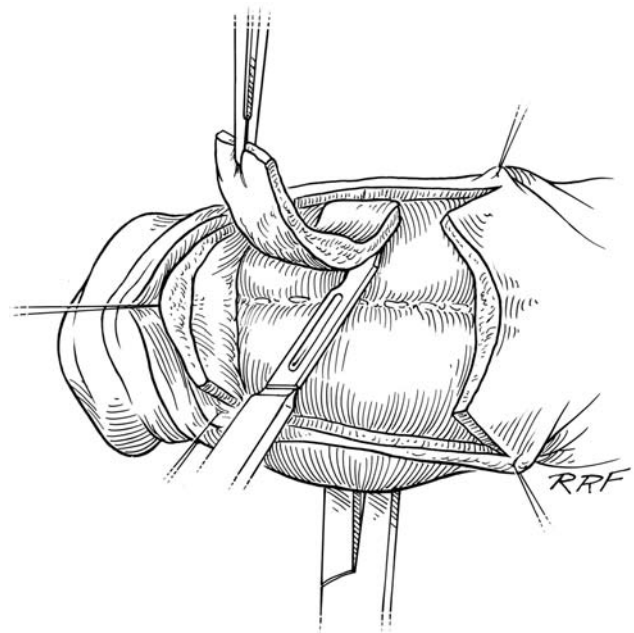


Figure 83.4 The midline strip of tunica albuginea is excised.

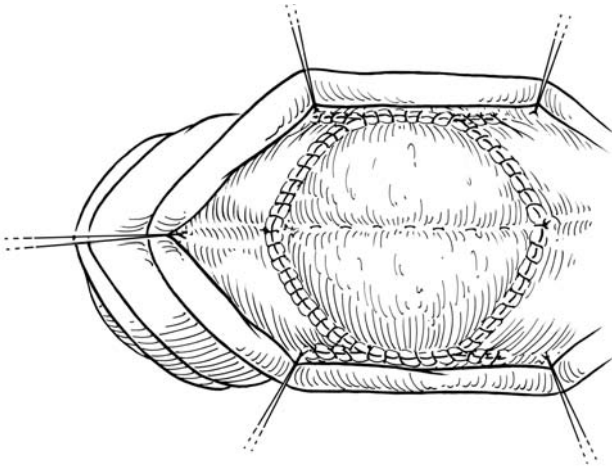


Figure 83.5 The appearance of the corporotomy defect with a graft in place. The case shown illustrates the use of dermis or of matrices such as pericardium or small intestinal submucosa.

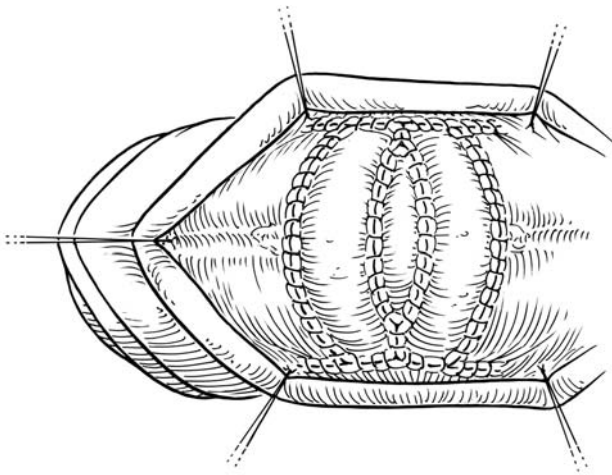


Figure 83.6 The appearance of the corporotomy defect when vein graft is used. In the case of the vein graft, the graft has to be sutured into a 'quilt' and then placed in the corporotomy defect.

If one is going to use dermis, the dermal graft can be harvested from overlying the iliac crest (roughly at the point of the 'love handles'). This graft donor site is relatively non-hirsute, although with correct de-epithelialization, the hair follicles should be removed in the de-epithelialization process. More importantly, with the use of a uniform donor site, one then achieves a uniform graft. It is well recognized that the thickness of the dermis varies throughout the body. We feel it is essential to use a donor site which gives a uniform graft thickness, as thickness is very important with regards to predictability of the eventual physical characteristics of the graft.

The corporotomy defect is carefully measured. A graft donor site is then marked, as indicated in Figure 83.7,

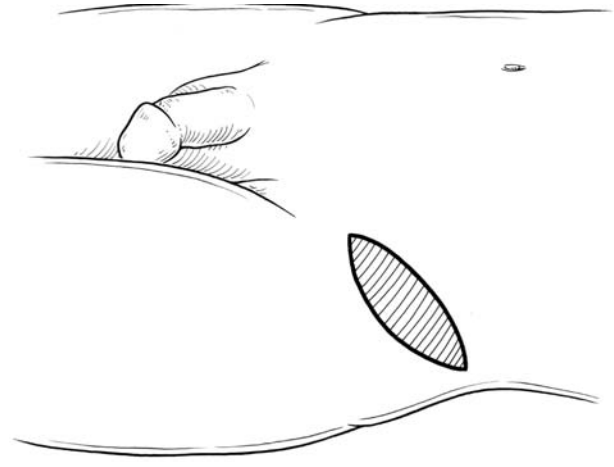


Figure 83.7 Donor site for dermal graft.

which allows for contraction of the graft by about 30–40%. It must be kept in mind that dermal grafts, per se, do not contract much as part of the process of take. However, when the dermal graft is released from the adjacent tissues, it then is not under inherent tissue tension, and the resultant graft will be smaller than the defect by about 30% in all dimensions. By aligning the long axis of the donor site with the Langer's lines, the ventral donor site scar will be very acceptable with very little tendency towards hypertrophic healing.

With the donor site marked, a superficial incision is made around the donor site. The incision is purposefully not carried through the depth of the dermis, the incision is to allow and facilitate the de-epithelialization process.

The scalpel blade is then placed parallel to the skin, beneath the edge of the epithelium, and the epithelium is removed from the underlying dermis. This can be done relatively easily. There are a number of 'tricks' that facilitate the process. For one, the donor site should be kept on tight lateral stretch by the surgeon's assistant. The use of a no. 10, very sharp, scalpel blade is essential. I prefer to roll the epithelium in front of the scalpel; I find that elevating the epithelium often tends to unacceptably thin the dermal graft. The scalpel almost defines the plane of the de-epithelialization by itself. If one finds that the epithelium is starting to 'hole' as it is being removed, change scalpel blades, as inevitably, the surgeon has subconsciously begun to push harder on the scalpel blade and hence wander from the correct plane. With the donor site de-epithelialized, then the incisions are deepened into the subcutaneous fat. The dermal graft can be harvested from the fat, with very little of the fat taken with the graft. This is done by beginning at the tip of the flap, a hemostat is placed right on the tip of the graft, and then the graft is rolled up onto the finger as the scalpel is used to find the layer between the

deep aspect of the dermis and the underlying fat. With the dermis harvested, if there is any underlying fat carried on the deep surface of the graft, then that can be removed easily with scissor dissection.

The edges of the donor site are then minimally undermined. A trick to avoid dog ears at the donor site is not to make the donor site overly ovoid or elliptical in configuration, but rather to make the tips somewhat concave. I close the donor site with subcutaneous Vicryl sutures placed deeply into the dermis, designed to evert the edges of the skin.

We have found that a Prolene suture placed in a running horizontal mattress can be pulled out, and the resulting scar is very acceptable. By using Prolene sutures and pulling them out, there is very minimal suture reaction. Certainly, however, with the longer acting monofilament absorbable sutures, the skin edge itself can be opposed with a running either vertical or horizontal buried mattress subcuticular suture.

The dermal graft will have two plexuses exposed, the intradermal plexus is exposed on the superficial aspect of the graft, and the deep dermal plexus is exposed on the deep aspect of the graft. Ostensibly the graft can take based on either or both of the plexuses. Certainly the erectile tissue is an optimal graft host bed, hence the graft is placed with the deep aspect against the erectile tissue. Thus, the deep dermal vessels will be exposed to that tissue; the superficial dermal plexus will then be in coaptation with the deep surface of the elevated Buck's fascia. The fact that these two plexuses are connected with perforating vessels, may contribute to one of the difficulties with using the dermal graft, which is the occurrence of graft induced veno-occlusive dysfunction. It appears that in the patient with global veno-occlusive dysfunction that the deep vessels can be involved in the 'leak' process, and then connect directly via the perforator to the superficial plexus which of course will be in connection with the intermediate vasculature of the penis. None of this has been proven by dissection, but certainly in patients who have developed graft induced veno-occlusive dysfunction, the appearance on cavernosogram would suggest that.

The graft is then tailored into the defect as with any other graft. The penis is placed hyperflexed; this slightly oversizes the graft, but it should be remembered that the graft has been oversized during the harvest process. The fact that the graft is not sutured under tension defects oversizes the graft as the graft will have 'contracted' approximately 30% based on being released from adjacent tissues. This 'contracture' occurs because of inherent tissue tension.

With the use of the inert collagen matrices, there is no tissue contraction due to inherent tissue tension, and these grafts must be oversized. In the case of SurgiSIS Biodesign, we oversize by approximately 30%. We achieve this by suturing the defect with the penis hyperextended. The graft inlay is completed using 4-0 PDS suture. An artificial erection is performed at the end of the procedure to demonstrate that the penis is straight and that the suture lines are watertight. If the penis is not straight during surgery, then it will probably not be adequately straightened postoperatively; if curvature persists then either further adjustment of the graft must be accomplished or touch-up plication may be necessary.

After completion of the graft inlay, the penis is anatomically closed. Drains are placed superficial to the closure of Buck's fascia but deep to the closure of the dartos fascia.

A minimally compressive dressing is applied using one of the transparent dressing materials. In most patients, a very minimally compressing Kling dressing is placed over that dressing. The minimally compressive dressing is left in place for about 4 hours and is then removed by the nursing service. We leave a catheter in place overnight. On the morning of the first postoperative day, the drains and catheter are removed. The vast majority of patients are in the hospital on a 23-hour observation basis.

While we do not encourage patients to have intercourse immediately after surgery, we do encourage them to have erections. We are liberal with the use of phosphodiesterase-5 inhibitors where necessary, and all patients are instructed in a protocol of provoking erections and massage of the penis. We allow our patients to resume intercourse at about 10–12 weeks postoperatively. It is not unusual, for patients during the first couple of months, to notice some diminished sensation on the glans penis; however, in our rather large experience, this inevitably corrects such that if there is any residual neurapraxia, it is not troublesome and the patients do not complain of it. It must be emphasized, however, that we do not test all of our patients postoperatively with regards to sensation. If there are patients who complain of diminished sensation, then indeed they are tested. To our knowledge, in hundreds of patients, we have only two patients in whom their postoperative sensation was altered such that it created problems for them with intercourse. By adopting the available techniques to patients with Peyronie's disease, the vast majority can have their sex lives re-established.

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84 Correction of Peyronie's disease: plaque incision and venous grafting

William O Brant, Anthony J Bella, and Ton F Lua

INTRODUCTION

Significant penile deformity due to Peyronie's disease may lead to severe functional limitations and psychologic trauma. Often, the plaque may lead to penile curvature, shortening and/or malconfigurations (hour-glasses, indents) that cannot be addressed with simple plication procedures. In these complex cases, plaque incision or excision combined with placement of a graft allows for reclamation of some of the lost penile length and girth. In addition, this procedure can be tailored to correct a variety of plaque-induced malconfigurations of the penis.

PLANNING AND PREPARATION

The patient should have good erectile function with penile curvature inhibiting sexual intercourse. Patients with good erectile function (i.e. requiring no pharmacotherapy to have a rigid erection) have a 10–15% risk of postoperative erectile dysfunction (ED) within 6 months. If erectile function is compromised preoperatively, risk of further decline may be much higher. Patients with a history of coronary artery disease who are at an increased risk of future coronary artery bypass grafting procedures should not undergo saphenous vein grafting; other graft materials such as porcine dermis, intestinal submucosa, or bovine or human pericardium may be more appropriate in this setting. In addition to ED, patients must be aware of the risks of temporary or permanent penile hypo- or anesthesia, future plaque formation, and de novo or recurrent curvature.

The single most important aspect, as with most surgeries, is patient selection. A grafting procedure may help the patient regain some degree of penile length lost from the underlying fibrosis, but there is an attendant risk of de novo ED. Patients, especially those with baseline ED, must be aware of this, and should always be counseled regarding the option of a penile prosthesis. We inform patients that a prosthesis may be placed at a later date, should the need arise. In high

risk patients, it may even be preferable to perform a two-stage procedure, as the substantial increase in operative time if both grafting and prosthesis are performed at the same setting may carry a higher risk of perioperative prosthetic infection.

An additional important factor in preoperative counseling is to address patient expectations about postoperative penile length. Many patients are understandably distraught about the penile shortening that often accompanies Peyronie's disease. However, they often have an unrealistic recollection of their past erectile length and we rarely can demonstrate this in any objective fashion, since we seldom have pre-morbid penile measurements available. The stretched penile length is routinely documented in the patient record and he is made aware that the procedure is usually limited to adding ½ to 1 inch to the stretched flaccid length. Patients need to be educated that a simple plication surgery may result in a straight erection but will not restore any length; a grafting procedure may restore some length but cannot exceed more than 1 inch above the stretched length of penis.

Materials

Special equipment necessary for the procedure includes:

- injectable saline for artificial erection
- silastic block for graft preparation
- vascular closer stapler (VCS) 1.4 mm titanium vascular stapler (for fashioning graft, 5-0 and 4-0 Maxon™ Syneture, CT, USA, for suturing the graft in place)
- a pair of blepharoplasty scissors for dissection of neurovascular bundles.

Patient preparation

We ask the patient to take photographs of the erect penis from several angles. If they cannot or will not do this, informed consent is obtained, allowing for the induction of a pharmacologic erection in clinic to document

the length and degree of curvature. In addition, we perform a color duplex ultrasound to document the lesion characteristics (calcifications, etc.) and assess penile vascular function. Preoperatively, the patient is given a single dose of a first-generation cephalosporin and the operative area is depilated using a clipper.

The patient is placed in the supine position. If a saphenous vein graft (SVG) is to be used, the non-dominant leg is placed in a slightly flexed and abducted position (frog-leg) with appropriate support and padding.

SURGICAL TECHNIQUE

The surgery is undertaken as outlined below. A circumcision incision is made and the penis degloved. The deep dorsal vein (DDV) is dissected out and tied off proximally and dorsally. This allows mobilization of the neurovascular bundles (dorsal arteries and nerves) bilaterally to the corpus spongiosum. Using a Jake or other fine-tipped clamp and a pair of blepharoplasty scissors, elevation of the tissue containing the neurovascular bundle is begun (Figure 84.1). We generally work from medial to lateral, although one may work from the other direction. It should be noted that this tissue should mobilize easily in the setting of normal tunica. However, the tissue overlying the Peyronie's plaque is often very adherent and care must be taken to not injure the artery or nerve. Loupe magnification should be used. To minimize potential for crush injuries to the nerve, we retract tissue using gentle finger retraction. For ventral curvature, the corpus spongiosum is similarly dissected free from the corpora cavernosa.

The extent of the plaque (for excision and grafting) or an 'H' shaped incision line crossing the middle of the plaque (for incision and grafting) is marked with a marking pen. An artificial erection is created at this time to judge the effect of the plaque on the curvature (Figure 84.2). A 21 gauge scalp vein needle is placed into one corpus, preferably in an area that will be incised or excised. One hand is used to compress the proximal corpora as proximally as possible, squeezing between the thumb and index finger, while injectable saline is infused through the needle. It is difficult to place a tourniquet proximally to the extent required, and the degree of the curvature may be underestimated. In addition, placing a tourniquet directly over the dorsal nerve may cause prolonged numbness of the penis. For 'H' shaped incisions, the site of greatest curvature and area(s) of narrowing are marked. An 'H' is drawn and the middle bar marks the center of the curvature (Figure 84.3). Side bars extend along the

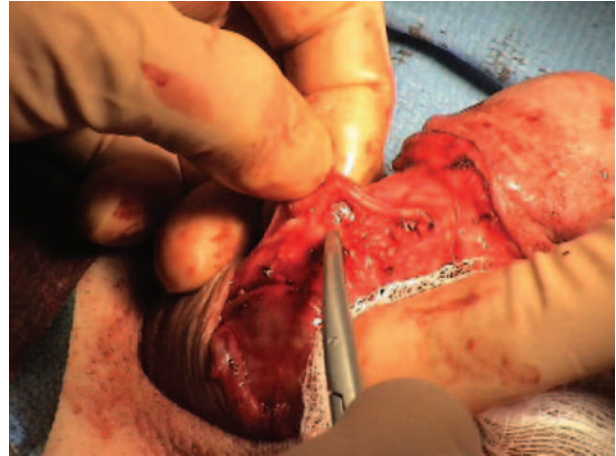


Figure 84.1 Dissection of the dorsal neurovascular bundle off the plaque.



Figure 84.2 Creation of artificial phalloerection.



Figure 84.3 The center of curvature is marked, including side bars for indentations.



Figure 84.4 Incision of plaque.

axis of the penis; these markings can also be used to address areas of narrowing, so their length and direction will depend on the characteristics of the curvature. This is the most crucial step in the procedure.

The site is then opened along the markings and spread so that the size of the defect both longitudinally and transversely can be measured (Figure 84.4).

Excision of a large plaque carries a higher incidence of ED. Most cases will do well with incision and grafting. The only time we excise tissue is when the patient has an extensive calcified plaque.

For a SVG, the impulse of the femoral artery is palpated in the inguinal region and an incision is made to expose the greater saphenous vein. Care should be taken to control more superficial vessels and lymphatics. The vein usually has an approximate diameter of 0.5 cm, so each segment will be approximately 1 cm wide once opened. This guideline helps determine how much vein to harvest. To avoid a long incision, we typically make several smaller incisions and tunnel the vein out, taking care to ligate tributaries with Dexon™ (Syneture, CT, USA) suture ligatures (Figure 84.5). Meticulous hemostasis must be obtained. The wounds are then irrigated and packed with moistened pads while the graft is prepared. The wounds are closed in two layers using absorbable sutures for Scarpa's fascia and a subcuticular layer.

If using vein, it is important to harvest an adequate amount. For example, if the defect in the H incision measures 5 cm wide by 3 cm high, choose a vein length of approximately 17 cm to yield 5 × 3 cm segments with a small surplus of material. It is important with SVG to determine how much vein to harvest, as harvesting additional vein once it has been ligated distally is tedious and inefficient.

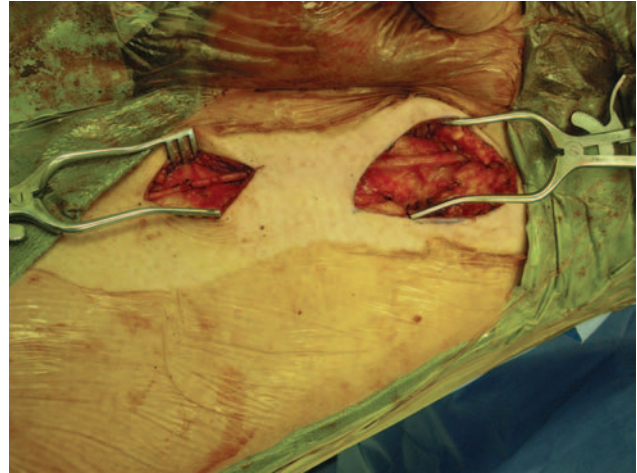


Figure 84.5 Harvesting of saphenous vein via two incisions to allow tunneling.

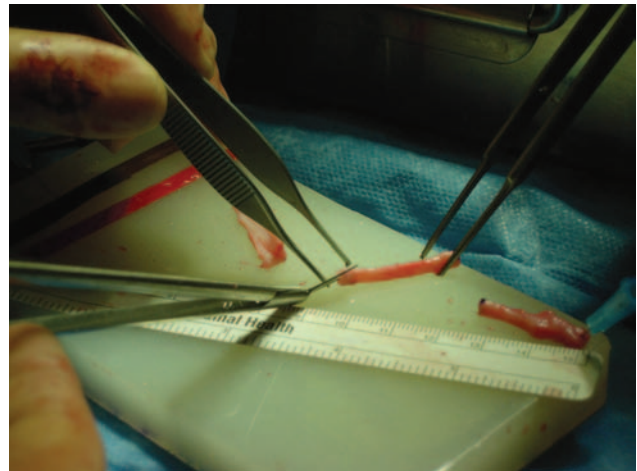


Figure 84.6 Division of vein.

Vein has the least contraction of any of the biologic graft materials; it is easier to tailor to size than other graft choices and this is discussed below.

The vein is divided into segments (Figure 84.6). Tributary sites are opened during division to minimize postoperative leakage. Short 25 gauge needles are used to anchor the vein to the silastic block while 5-0 Maxon is used to suture both ends of segments together and the sides are joined using VCS titanium vascular staples (Figure 84.7). The graft is kept moist until it is used.

Many other graft materials are available. Varying degrees of contracture are expected after placement and we recommend tailoring a graft that gives approximately 25% larger area than the defect.

The corners are sewn into place first, using 4-0 Maxon. The remainder of the graft is sewn into place in a running, locking fashion. Leaks tend to occur at the corners where the running suture goes around the previously placed corner knots. This may be avoided by

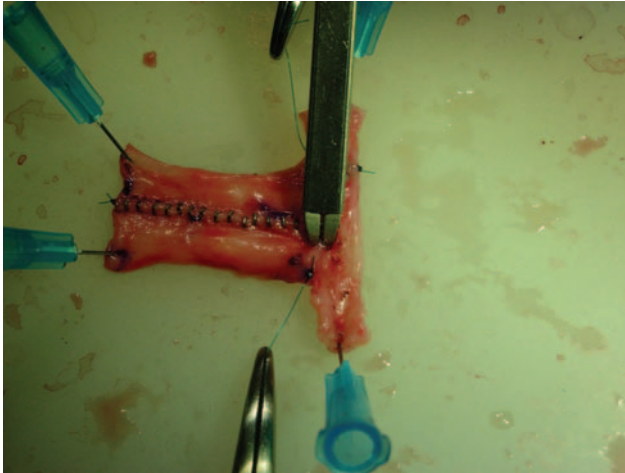


Figure 84.7 Preparation of graft. The central portion has been done, one of the side bars is being made.

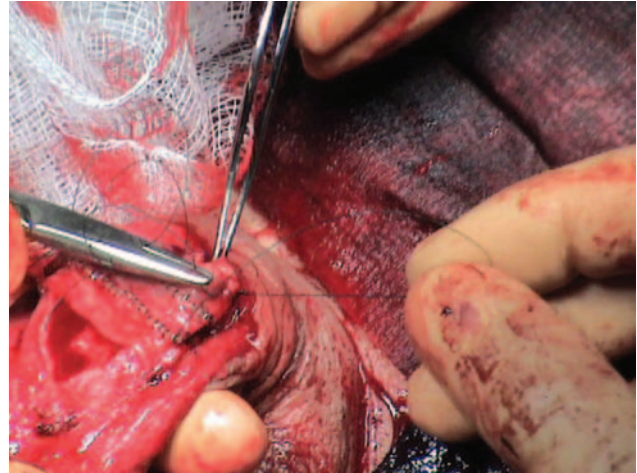


Figure 84.8 The graft is being sutured into place.

Table 84.1 Plaque incision and grafting: trouble shooting

Problem	Solution
Difficulty encountered mobilizing the neurovascular bundle(s)	Starting lateral to the plaque, and beginning the mobilization from a lateral (over normal tissue) towards medial direction
The plaque has an hourglass, circumferential distribution	The tunical incision is made on the lateral aspects and the graft placed vertically
The patient has postoperative pain with nocturnal erections although daytime discomfort is minimal	We make the patient aware of this discomfort and have him take analgesics prior to sleep
The patient notices a new bulge at the site of the graft 2–3 months postoperatively, after he has had a strong erection	This may be representative of a hematoma, particularly if materials other than venous graft are used. We perform an ultrasound and, if a hematoma is identified, we aspirate it under ultrasound guidance

not locking the stitch at these sites and by placement of the sutures closer together in this area (Figure 84.8).

Artificial erection should confirm an appropriate shape and will identify any leaks in the graft. Any leaks are closed with 5-0 Maxon. Once the graft is watertight, a few sutures are loosely placed to return the neurovascular bundles to their original site.

An artificial erection is created again with injection of normal saline. If the penis is not straight, plication sutures (2-0 Ticron™ Syneture, CT, USA) are placed to straighten the penis and protect the graft from bulging. Several interrupted subcutaneous sutures are placed using 5-0 Maxon, and the skin is closed using two running, locking 5-0 Dexon sutures.

The dressing consists of a xeroform™ (3M, MN, USA) gauze around the incision, followed by a loose wrap using a gauze pad. Coban™ (3M, MN, USA) adhesive compression dressing is placed without constricting the penis, wrapped from distal to proximal. The dressing is then 'squeezed' around the penis to make it snug but not constrictive. We mark the end of

the coban with a marking pen to aid the patient when we teach him to change the dressing the next day, which he will do daily for 10 days. The use of an ice pack is emphasized, and is routinely applied for the first 24 hours to minimize pain and swelling.

A guide to trouble shooting in plaque incision and grafting is shown in Table 84.1.

OUTCOMES

The most common complications after venous grafting surgery are penile shortening, residual curvature, and worsening or de novo ED. In general, approximately 4–20% of patients have some degree of residual curvature, although this does not preclude sexual intercourse. Furthermore, 6–20% have worsening ED, although this may be as high as 45% in those with preoperative ED.¹ Additionally, longer follow-up may demonstrate worsening ED over time, particularly in patients with vascular risk factors, suggesting that

Table 84.2 Frequency of patient outcomes after plaque incision and grafting

Study	Penile shortening	Erectile dysfunction	Residual curvature	Overall satisfaction
El-Sakka et al, 1998 ¹	17%	12%	4%	92%
Kadioglu et al, 1999 ³	0%	7%	20%	100%
Arena et al, 1999 ⁴	50%	13%	4%	83%
Montorsi et al, 2000 ⁵	40%	6%	14%	88%
Adeniyi et al, 2002 ⁶	35%	12%	18%	92%

there may be acceleration of microfibrosis of erectile tissue after grafting procedures.² Penile shortening occurs in 0–17%. Although complication rates are increased in comparison with simpler Peyronie's disease procedures, overall satisfaction with venous grafting occurs in 90% of the patients (Table 84.2).¹

CONCLUSIONS

Procedures for Peyronie's disease deformities that involve auto- or xenografting allow even the most complicated deformities to be addressed. Although the rates of complications are increased, patient satisfaction is also high. As with many surgeries, appropriate patient selection and managing patient expectations are the two key features in ensuring a successful operation.

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85 Peyronie's disease: non-autologous graft materials

Dudley Atkinson and Wayne JG Hellstrom

INTRODUCTION

The option for surgical management of Peyronie's disease usually follows the failure of medical treatment modalities and the observation over approximately 12 months that the severity of disease is no longer progressing, as measured by no change in plaque size or penile curvature. Patients with adequate erectile function can derive satisfactory surgical outcomes using plication-type procedures. Plication is considered primarily in those men with Peyronie's disease with less than 60° of uniplanar penile curvature, absence of hourglass deformity, average or longer than average penile lengths, or ventral curvature.

Excision or incision of a plaque with graft placement is a well described technique. It has the theoretical advantage in that penile length is not reduced by the procedure, and thus is more appealing to most informed patients. It also allows repair in those who would be less likely to have a good outcome from plication alone since the introduction of the graft material adds support and a normal shape to the penile deformity. Grafts provide important benefits in cases of complex curvature, hourglass deformity, or hinge defects. Results are particularly beneficial for patients who demonstrate adequate spontaneous or vasoactive drug-induced erections with normal vascular supply on penile duplex Doppler ultrasound.

Patients with erectile dysfunction in addition to Peyronie's disease need to be carefully evaluated for the provision of an inflatable penile prosthesis along with correction of the curvature by a modeling procedure and, if necessary, employing a graft. This may be done without significant increased risk of complications compared with penile prosthesis alone. Men with curvatures greater than 60° generally should also be counseled regarding the likely need for prosthetic implantation.¹⁻⁴

GRAFTING MATERIALS

The ideal grafting material has not been identified. Synthetic grafting materials have not shown good

Table 85.1 Non-autologous graft materials

Synthetics

Gore-Tex™ (W.L. Gore & Associates, Newark, DE)

Dacron™ (Wilmington, PE)

Silicone with Silastic borders

Allograft/xenografts

Human cadaveric pericardium

Porcine small intestinal submucosa

Cadaveric dermis

Collagen fleece with clotting factors

results in the absence of concomitant prosthetic implantation, with the exception of a material composed of silicone with Silastic™ (Dow Corning, Midland, MI) mesh borders, which is no longer manufactured for medical purposes (Table 85.1). Typical complications of grafts used in Peyronie's disease cases include graft contracture, recurrent curvature, worsening erectile dysfunction, and higher morbidity secondary to autologous graft harvesting.

Non-autologous grafting materials possess many advantages that merit attention for those patients who would benefit from their use. They do not require a second incision for the harvesting of graft tissue, and the meticulous preparation necessary to remove fat and other connective tissues is unnecessary. They may be stored for long periods of time and are used as needed from stock supplies. Their preparations are standardized and the quality of the material is very predictable.

BASIC MATERIALS RESEARCH

Recent progress has been made through the use of resorbable extracellular xenograft matrices, created by processing donor tissue to create an acellular sheet. Early work was done using cadaveric dura mater with good results, but some cases of iatrogenic Creutzfeldt-Jacob disease have been reported. The cadaveric sources primarily used today in clinical development are porcine small intestinal submucosa (SIS) and human pericardium. Studies have also been conducted with

porcine dermis, bovine pericardium, and other materials. Cadaveric tensor fascia lata has been reported in a cavernosal reconstruction following partial penectomy.⁵

A comparison of various graft sources was made using rat models in order to characterize possible differences between cadaveric pericardium, autologous vein, autologous dermis, and synthetic Gore-Tex materials. All grafts were able to withstand high intracavernosal pressures after electrical field stimulation with no loss of erectile function. However, a caveat about the results of this study was that the grafts used were smaller than the average size used in human operative procedures and may not be representative of the changes in erectile function after grafting in men with Peyronie's disease. The cadaveric pericardium allowed ample penile expansion and was strong enough during normal erections, with minimal development of fibrosis in comparison to Gore-Tex and with histologic responses similar to those observed with dermis and vein grafts.⁶

SIS graft material (Surgisis®, Cook Urological, Bloomington, IN) is prepared from pig jejunum by mechanically removing the mucosa, mucosa muscularis, and serosa, leaving the submucosa and basal mucosal layers. The SIS is stripped of fat, decellularized with paracetic acid, and then freeze-dried and stored. The final product is approximately 0.2 mm thick when reconstituted and is composed primarily of type I porcine collagen with growth factors and glycosaminoglycans present as well. It is minimally antigenic and is not rejected. Rather, it is gradually colonized by host tissue cells, blood vessel, and additional extracellular matrix provided by the host and is eventually resorbed (Figure 85.1).

Human cadaveric pericardium graft material is supplied as Tutoplast® (manufactured by Tutogen, Alachua, FL, and distributed via multiple suppliers). After removal from the donor, the tissue is processed in a serial multistep fashion to minimize antigenic potential and reduce transmission of infectious diseases. A solvent dehydration process is followed by 25 kGy gamma irradiation, rendering the substance acellular with microbial inactivation of bacteria, fungi, and viruses including HIV. The collagenous matrix after processing reportedly retains the strength and elasticity of native pericardium, with multidimensional expansion of up to 30%. It has an excellent tensile strength and is approximately 0.45 mm thick when reconstituted. Like SIS, it is gradually colonized and resorbed. At minor prosthesis revision, surgeons' inspection of the previous cadaveric pericardium graft site revealed complete host tissue regrowth with no



Figure 85.1 Small intestinal submucosa graft material sutured before being trimmed to size.

observable pericardial graft material, but no tissue biopsy was obtained. This demonstrates cadaveric pericardium acting as a scaffold while normal tissue grows in to replace it over a number of months.⁷

CLINICAL EXPERIENCE

Knoll describes a series of 12 patients treated by plaque incision and SIS grafting in a cohort group aged 39–61 years. All subjects reported absence of pain with intercourse and no progression of penile curvature in the preceding 10 months. Eleven had full and one had partial erectile rigidity, but none were able to penetrate vaginally secondary to the penile curvature. Four patients had lateral curvature and eight had dorsal curvature. Plaques ranged from 2 × 4 to 3 × 6 cm in size, and all candidates had demonstrated penile curvatures greater than 70°. Results were evaluated using home photographic documentation and clinic follow-up 3 months postoperatively. At follow-up from 5 to 20 months, 11 of the 12 patients had less than 10° curvature. One patient, who had the largest plaque preoperatively and was the first in the series, had recurrence of curvature more than 60° with indentation requiring reoperation. Two patients complained of transient penile hypoesthesia, but none reported penile shortening or pain. All were able to have satisfactory sexual intercourse after surgery, although one was with the aid of intercavernosal vasoactive injections at home.⁸

Knoll describes in a second study a series of patients who required repair of tunical deficiencies after implantation of inflatable penile prostheses. Seventeen patients had at least a 36-month history of implantation,

after which nine had unilateral distal erosion of the tunica and eight had tunical attenuation. All underwent prosthesis revision with tunical reconstruction utilizing SIS as the graft material. At 6–34 months of follow-up, no patient had separation of the graft from the tunica or recurrence of the deficiency.⁹

Researchers in two separate studies described a series of 40 and 11 men, respectively, who received Tutoplast human cadaveric pericardium. In the former, 43 patients were grafted, but three with simultaneous penile implantation were excluded from the retrospective study. The group was aged 32–65 years. They were subjectively tested for preoperative erections, and 36 of 40 could sustain an erection adequate for intercourse were it not for their deformity. The remaining four could attain a satisfactory erection following papaverine intracavernosal injection. Penile curvature ranged from 60 to 140°. Only 29 could achieve coitus before surgery. At follow-up from 2 to 10 months, 38 of the men had achieved coitus, 28 of them with full, unaided erection. Of the 40 men 12 had some degree of erectile dysfunction, but only two failed to achieve an erection adequate for intercourse after using sildenafil citrate or a combination of sildenafil citrate, alprostadil intracorporeal injection, and/or a vacuum constriction device.¹⁰

In the first Peyronie's disease study using cadaveric pericardium, a total of 11 patients from 44 to 71 years of age with disabling penile curvature interfering with sexual intercourse were evaluated. Plaques ranged from 3 to 7 cm long. In three men erectile dysfunction was documented secondary to vascular insufficiency detected during preoperative penile duplex Doppler ultrasound studies, and consent was granted for the prosthesis option. After failed manual modeling over inflatable penile prosthesis cylinders via the penoscrotal approach, all three underwent plaque excision/incision and pericardial grafting over the prosthesis. At 9–19-month follow-up visits, all 11 patients had successful sexual intercourse, nine had complete resolution of penile curvature, one had 10° curvature, and one had progressed from 10° to 30° curvature at 18 months.¹¹ Another study that compared cadaveric pericardial grafts with dermal grafts found similar results and reported that cadaveric pericardium yielded performance comparable with, if not better than, dermal graft material.¹²

OPERATIVE TECHNIQUE

The procedure for plaque excision or incision with grafting varies between centers, but an overall description

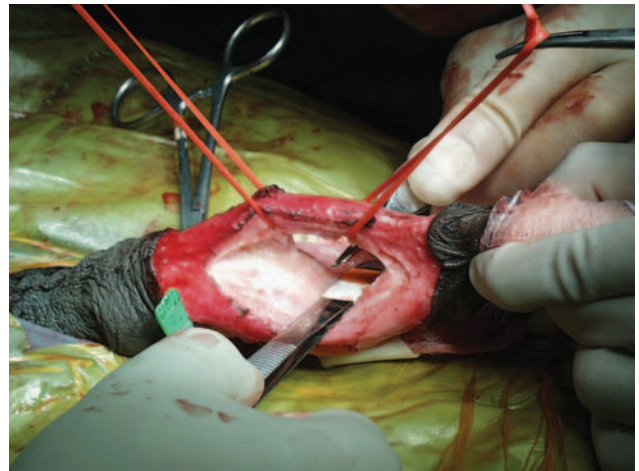


Figure 85.2 Lifting the urethra to excise plaques on the ventral midline.

of the steps is provided, based upon a modified Horton-Devine procedure. Before surgery patients generally receive antibiotics. In our center, out of convention we still use vancomycin and levofloxacin. General or spinal anesthesia is provided for the surgery. A standard circumcision incision is used with subsequent degloving of the penis. Buck's fascia is entered in most cases just lateral to the urethra with care taken, with surgical loupe magnification in some situations, to dissect under the neurovascular bundle free of dorsal plaques and the urethra free of ventral plaques (Figure 85.2). A midline approach excising the deep dorsal vein can be used to approach long, narrow dorsal plaques directly.

Artificial erections are used to delineate the severity of penile curvature and plaque dimensions at the start of the procedure and at different stages to assess the degree of straightening achieved by the repair. With cadaveric pericardium, the plaques are carefully marked and incised or excised sharply, taking care to avoid injury to the underlying cavernosal tissue. If incision is elected, the center of curvature of the plaque is marked and a relaxing incision made, extending the ends into a variation of the 'H' shape if required (Figure 85.3).

The graft material is soaked in normal saline solution with or without antibiotics for a few minutes, then tailored approximately 1–2 mm (or 10%) greater than the size of the tunica albuginea defect as measured with the defect at full stretch. The grafts are secured with a running 5-0 polydioxanone suture. Interrupted septal sutures may be elected in order to prevent the accumulation of a subgraft hematoma (Figure 85.4).

Erection is induced again to ensure adequate repair. The overlying layers of penile fascia are closed in layers

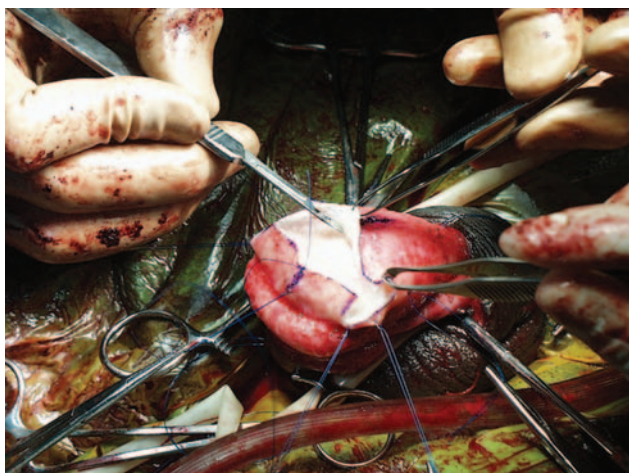


Figure 85.3 Incision of the 'H' shaped variety.

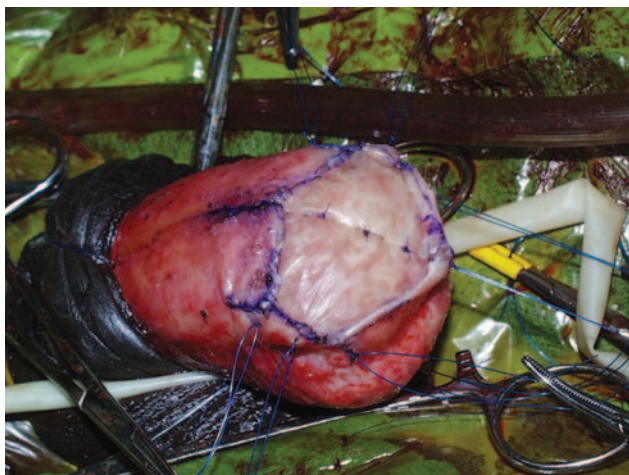


Figure 85.4 Interrupted septal sutures to minimize risk of subgraft hematoma.

with a loose Coban™ (3M, St Paul, MN) dressing applied for 2–3 days. The 14 Fr Foley catheter is removed in the recovery room. Patients continue on prescribed antibiotics (fluoroquinolone) for 7–10 days and are instructed to abstain from intercourse for 6 weeks. Patients have more recently been instructed to use a vacuum tumescence device without the constricting ring for 20 minutes per day or to use sildenafil 25 mg nightly starting approximately 4 weeks postoperatively.

COMPLICATIONS AFTER GRAFTING

Hematoma is the most likely complication after grafting, and is minimized through careful intraoperative hemostasis. The use of septal sutures has been shown to reduce the incidence of hematomas in our center. Wound infection is prevented through the use of intra- and

postoperative antibiotics, in concert with meticulous sterile preparation and procedure. Urinary retention or urethral injury is possible, and since the Foley catheter is removed shortly after the procedure, a potential for urethral stricture exists in this circumstance. Distal sensory deficit or numbness in the glans (neuropraxia) can occur due to either nerve ligation or stretch injury.

Diminished distal rigidity secondary to possible venous leaks or graft leaks is distinctly possible and is a reported complication. Some patients may find it necessary to use a vacuum device or Actos™ (Panacea Pharmaceuticals, Gaithersburg, MD) ring to achieve an erection. Graft contraction in the area of repair may occur leading to recurrence of curvature. This is particularly likely with the use of synthetic materials. One or all of these complications can result in erectile dysfunction secondary to changes in sensation, function of the corpus cavernosum, or other causes.

Thiel et al reported one case of a 2 cm inclusion cyst 3 months postoperatively. In the initial repair after the excision of a 2 × 3 cm plaque, the lesion was grafted with human cadaveric pericardium. The patient presented for 3-month follow-up with a painless cyst over the graft site. The complication was resolved through a second procedure with the use of an autologous temporalis fascia graft, after which the patient reported satisfactory erections without return of the cyst.¹³

INVESTIGATIVE GRAFTING TECHNIQUES

A novel approach has recently been described by Lahme et al, using collagen fleece to cover tunical defects after partial incision of plaques. The ready-to-use collagen fleece is supplied as TachoComb® (Nycomed Pharma GmbH, Ismaning, Germany) and is coated with human fibrinogen and thrombin. After cutting the product to the size of the defect left by plaque removal and wetting with normal saline, the fleece is manually compressed onto the defect for approximately 3 minutes. Closure is as above. In total, 18 patients were available for follow-up. These ranged from 30 to 76 years of age, with penile deviation of more than 45° and either painful coitus or an inability to achieve vaginal penetration. The average defect measured 1.3 cm². At 2–58 months of follow-up, 15 patients improved as measured by less than 15° residual penile deviation, no new cases of penile deviation, absence of reduced glans penis sensitivity, and no occurrence of erectile dysfunction.¹⁴

SUMMARY

While non-autologous grafting materials are not the perfect material for the repair of severe Peyronie's disease, they do have the distinct advantages of ready shelf availability, easy handling, and not requiring the patient to have tissue harvested from a second site. Diminished operative time also translates into lowered cost as well. A number of studies have reported excellent clinical results for a large percentage of patients using SIS or human cadaveric pericardium as the grafting material. Both of these materials are processed to have minimum or no immune response, and they are reported to be resorbed by the body after acting as a scaffold for tunica albuginea repair in the area of the graft.

The operative technique is similar to that used for other grafting materials and yields similar results to those obtained with autologous materials. The techniques described have been employed in enough patients to demonstrate their efficacy and are appropriate for many men with Peyronie's disease who elect the surgical option. The complications noted are not particular to the non-autologous materials as they are shared amongst all grafting materials. Outcomes for non-autologous grafts are superior to grafts using synthetic materials and comparable with, if not better than, those using dermal materials.

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86 Total phallic reconstruction

A Nim Christopher and David J Ralph

BACKGROUND/HISTORY

In 1936 Nikolai Borgoraz from Russia published the first report of phalloplasty using a tubed pedicle technique.¹ Maltz (1946) and Gillies (1948) made the urethra and phallus simultaneously from an abdominal tubed pedicle flap, using a tube within tube technique.^{2,3} This was a multistage operation, using delayed pedicle transfer to reduce the risk of graft loss. The Gillies phalloplasty was the standard technique for the next 30 years. Chang and Hwang (1984) published the first report of the radial forearm flap phalloplasty using a tube within tube technique for the urethra.⁴ This phallus could develop sensation because of nerve anastomoses. The excellent aesthetic properties allowed the radial forearm flap phalloplasty to supplant the Gillies phalloplasty as the procedure of choice. The main drawback with this flap is the very visible donor site defect.

INDICATIONS AND COUNSELING

There are four groups of indications for phallic reconstruction summarized below in order of increasing surgical difficulty:

- Female-to-male gender reassignment
- Micropenis
- Traumatic penile loss
- Penectomy for penile cancer.

The phalloplasty techniques are basically the same, however, if there is some existing functional penile tissue, then every effort should be made to incorporate it into the new phallus. The patient should be counselled appropriately as phalloplasty surgery involves a number of operations and a significant complication rate. We split the surgery into four stages listed below, each of which can have multiple operations:

- Stage 1 – construction of phallus
- Stage 2 – construction of neourethra
- Stage 3 – cosmesis with glans sculpting, testis prosthesis, and reservoir insertion for penile erection device
- Stage 4 – cylinders and pump of erectile device.

In terms of the end result, it is possible to recreate all normal penile anatomy except for the foreskin and all penile functions except ejaculation in gender reassignment patients. Consideration must be given to the donor site as skin, fat, and occasionally muscle and bone can be harvested for the phalloplasty. There will always be a donor site defect, usually covered with full- or split-thickness skin graft, and this may be a cosmetic problem for the patient.

PHALLOPLASTY TECHNIQUES

The most common phalloplasty technique now is the free-flap phalloplasty. The phallus is constructed at the donor site and then transplanted to the recipient site using microsurgical arterial, venous, and nerve anastomosis. This gives the best cosmetic results and lowest urethral complication rate. In addition as the phallus usually becomes sensate, there is a reduced erection device complication rate as the patient can feel that something is wrong long before it becomes irretrievable.

Other techniques involve a local flap such as the pubic phalloplasty (PP) and pedicled flap such as extended groin flap (EXTG) and some anterolateral thigh (ALT) flaps.^{5,6} The ALT flap can be either pedicled or a free flap.

Free flap phalloplasty

Donor site

The original description of radial artery free flap phalloplasty was by Chang and Hwang (1984), where they described the use of a radial artery based free fasciocutaneous flap from the forearm (RAP). The forearm skin is nice and thin with a reasonable amount of subcutaneous fat to give the phallus bulk. In addition the arterial pedicle is reliable, of a reasonable diameter and long. The medial skin of the forearm is usually non-hairy and this forms the urethra, further reducing complications. This is still the most common free flap phalloplasty despite the obvious and visible donor site defect. Other groups have tried alternative donor sites

Table 86.1 Alternative donor sites for free flap phalloplasty

Deltoid flap
Ulnar artery forearm flap
Latissimus dorsi flap (musculocutaneous)
Anterolateral thigh flap
Fibula flap (with and without bone)
Lateral thigh flap

in an attempt to reduce the donor site morbidity as listed in Table 86.1.

If the donor site is hairy, then the patient is offered laser hair removal for the urethral segment. If the skin surface area is limited, then the urethra is prefabricated using skin graft tubes 3–6 months before the flap is raised. We describe the radial artery free flap phalloplasty in detail as the other free flaps only differ in the vessel anatomy.

Radial artery phalloplasty

An Allen test should be normal in the donor forearm before radial artery phalloplasty. The radial and ulnar arteries are both compressed and the patient makes a fist to empty the veins before relaxing the hand. The ulnar compression is released. If there is prompt blood flow to the thenar eminence then this is good evidence that the superficial and deep palmar arches are connected so the hand should survive on just the ulnar artery. The non-dominant forearm should be used in case of functional problems postoperatively. If the pulses are weak or there is a history of wrist fracture or arterial/venous damage then formal Doppler ultrasound examination of the forearm vessels should be undertaken.

Once the patient is surgically prepped the forearm flap is raised under tourniquet after devascularizing the forearm. Usually a tourniquet pressure of 200 mmHg is sufficient. The time limit is 2 hours although the shorter the better. There are anatomic limits as to how much skin can be taken. At the wrist the incision should be no more distal than the ulnar styloid and preferably more proximal to reduce mobility problems at the wrist. At the elbow it should be at least 5 cm from the bifurcation of the brachial artery to the proximal incision to allow sufficient radial artery pedicle length. Most patients will get 12–15 cm in phallus length using these criteria. The urethral (ulnar) segment is 4 cm wide and up to 3 cm longer than the phallus segment depending on the amount of native urethra available. For those without an existing penile urethra such as gender reassignment patients then 3 cm longer is needed. The phallus segment is rhomboid shaped with the tip of the phallus

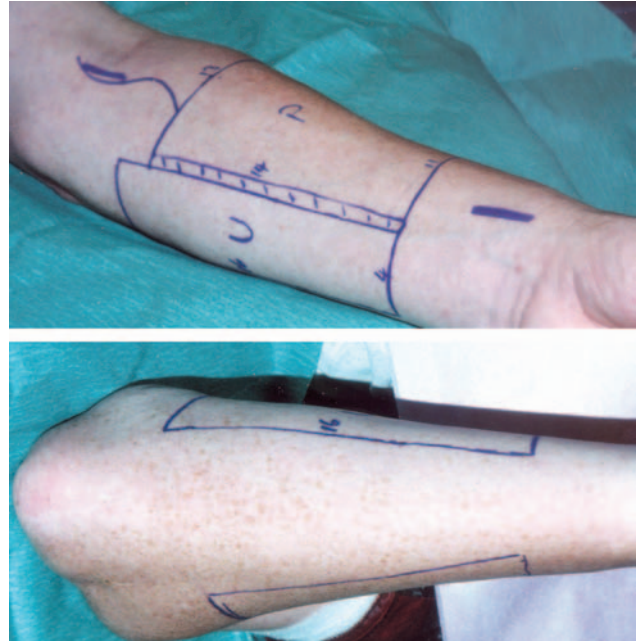


Figure 86.1 Typical forearm skin markings for radial artery phalloplasty.

being shorter in circumference than the base. This is because there is less subcutaneous fat distally. A typical dimension would be 13 cm for the base and 11 cm for the tip. If there is a very thick layer of fat then more skin width needs to be taken to allow the phallus to be constructed primarily without a skin graft. A de-epithelialized strip about 1 cm wide is fashioned between the urethral and phallus segments to act as a hinge and to maintain blood supply (Figure 86.1).

The dissection is normally carried out from distal to proximal although some surgeons prefer to get the vessels at the elbow isolated first. The radial artery, venae comitantes and other cutaneous veins are divided at the wrist and the flap elevated in a retrograde fashion. For patients with little subcutaneous fat or less experienced surgeons, the skin incisions are deepened through the deep fascia over the muscle and the whole flap lifted including the deep fascia. This makes it a little awkward to close the forearm defect so more experienced surgeons will only elevate the deep fascia for about 2–3 cm on either side of the radial artery pedicle. The small arteries and veins are ligated or surgically clipped for hemostasis. The radial nerve, with its superficial and deep branches, emerges from under the lateral edge of the brachioradialis tendon just proximal to the wrist and must be preserved (Figure 86.2). Sometimes there is a recurrent branch which loops back medial to the tendon which must

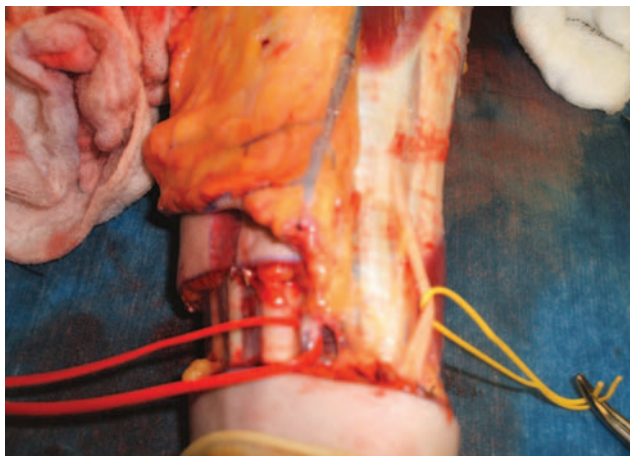


Figure 86.2 Forearm dissection under tourniquet showing radial nerve (yellow loop) lateral to brachioradialis tendon at the wrist and radial artery (red loop) medial to the tendon.

be divided. The radial artery runs up the forearm under the brachioradialis tendon and is released by sharp dissection, literally peeling the artery off the undersurface of the tendon, taking care not to damage the radial nerve which is in close proximity throughout. Particular care needs to be taken to preserve the friable fascial window between the radial artery and the lateral flap proximally as the blood supply runs through this. At the elbow the cutaneous veins are carefully isolated and followed proximally for 5–6 cm without dividing them. The medial cutaneous nerve of the forearm is fairly large and constant in position next to the cephalic vein. The lateral cutaneous nerve is not always present and sometimes there are cutaneous nerves on the urethral segment as well. These nerves need to be isolated and divided at least 5–6 cm long with a ligature on the end so they can be found easily later. If possible the venae comitantes of the radial artery can be traced up to the cephalic vein. As long as there is some deep venous drainage to the forearm, then the deeper veins can be divided taking the venae comitantes in continuity with the cephalic vein making for an easier microsurgical anastomosis. Otherwise the venae comitantes are divided and surgically clipped to find them later. The radial artery is followed to the bifurcation of the brachial artery, confirming the presence of the ulnar artery going deep. Once the flap is completely free except for the vessels the tourniquet is released and the flap re-perfused (Figure 86.3). Some topical vasodilator such as papaverine is useful at this stage. Bleeding vessels in the flap are diathermied with bipolar forceps and any bleeders on the radial artery pedicle clipped only. Once hemostasis is obtained the flap can be inspected for skin perfusion

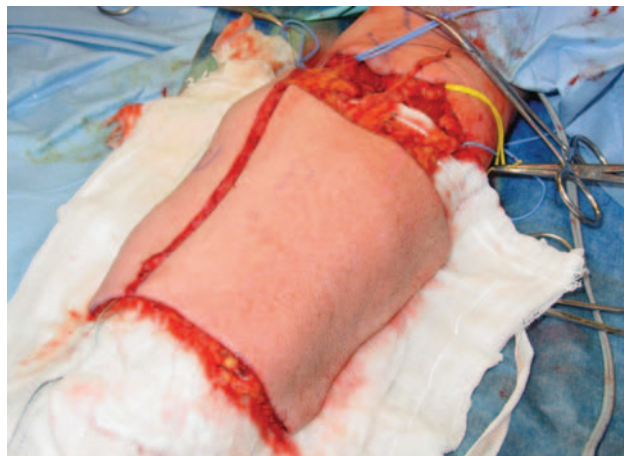


Figure 86.3 The forearm flap is allowed to perfuse once the tourniquet is switched off. The de-epithelialized strip acts as a hinge between urethral and phallus segments.

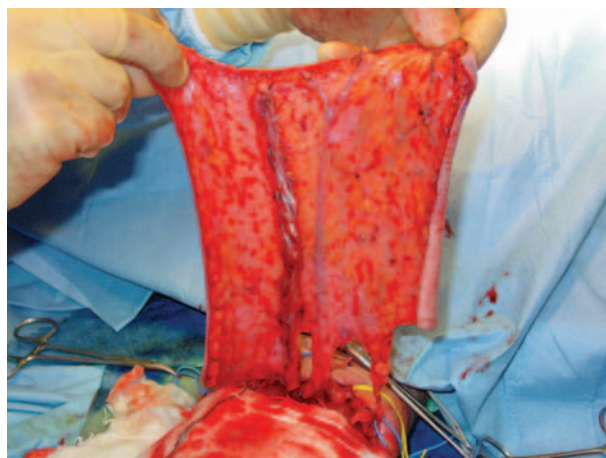


Figure 86.4 The flap is only connected by the radial artery pedicle, cephalic vein, and lateral flap vein going from left to right.

(Figure 86.4). The lateral edge is the furthest away from the blood supply and some of the edge may need to be excised if perfusion is poor. The urethra is tubed over a 16Fr stent using seromuscular 4-0 Vicryl™ absorbable interrupted sutures leaving a V-flap proximally of about 1.5 cm (Figure 86.5). The phallus skin is then wrapped around the neourethra and closed to the 'hinge' made earlier using either two layers of subcuticular Vicryl or a single layer of 4-0 Nylon interrupted sutures. If the phallus is very floppy, it is advisable to leave a Penrose drain. When the abdominal team is ready the radial artery is divided at the bifurcation of the brachial artery and the phallus end of the radial artery left free. The veins are clipped with large surgical clips to facilitate identification later. The phallus is then handed over to the abdominal team (Figure 86.6).

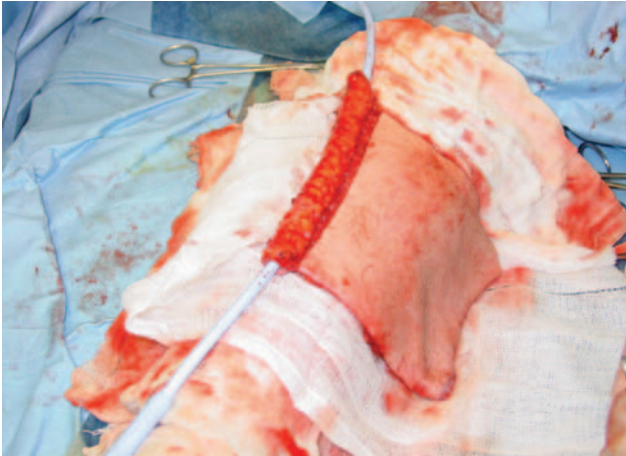


Figure 86.5 The urethral segment has been tubularized over a 16 Fr stent leaving a V-flap proximally.



Figure 86.7 Appearance of full-thickness skin graft to the forearm defect about 6 months later.



Figure 86.6 The phallus is completed by wrapping the phallus segment around the urethral. This one has had the glans sculpting done.

Once hemostasis of the forearm is satisfactory, the muscles are compacted by suturing the medial and lateral deep fascia together. The subcutaneous fat on the skin edge is trimmed to allow a gradual contour rather than a step-like defect when the skin edge is sutured to the muscle or deep fascia. With careful suturing it is possible to reduce the surface area of the defect by nearly 20%. A subcuticular 3-0 Vicryl suture is used to attach the skin edge to the muscle fascia. A full-thickness or split-thickness skin graft is placed on with 3-0 Nylon sutures. The largest and best piece of skin should be placed on the lateral aspect of the forearm which is the most visible. A silicone based dressing Mepitel™ (Mölnycke Health Care AB, Göteborg, Sweden) is used which does not adhere to the skin graft followed by layers of gauze, padding, and crepe

bandage. The dressing should be from distal to the metacarpal joints to proximal to the elbow to immobilize both wrist and elbow joints. It should not be too tight as that may lead to a compartment syndrome. The forearm is elevated in a Bradford sling for 7 days to reduce swelling (Figure 86.7).

Recipient site

The phallus needs to be placed so that its base is partly on the pubic bone and partly below. This allows space for the neourethra and erection device later. The part over the bone gives some stability for the microsurgical anastomoses. A circular pubic button of the same size as the phallus base is excised. The rest of the abdominal incision depends on what incisions the patient already has. If none, then a curved incision from the side of the pubic button to the iliac crest on one side allows access to the inferior epigastric artery (Figure 86.8). Our preference is to use a dedicated artery such as the inferior epigastric artery, rather than a saphenous jump graft to the femoral artery.

For micropenis patients the penis is disassembled into three components. The glans is mobilized on the dorsal neurovascular bundle using sharp dissection. The corpora cavernosa are divided at skin level and closed with absorbable sutures. The urethra is transected as long as possible to reduce the amount of forearm flap skin needed. The glans is wrapped around the neourethra and placed in the ventral suture line to provide erogenous sensation. The glans needs to be opened into a flat plate and may need reducing in size to fit (Figure 86.9).



Figure 86.8 Typical abdominal incision for radial artery phalloplasty.

Vessel preparation and anastomosis

To prepare the inferior epigastric artery an incision is made medial to the linea semilunaris in the lower abdomen. The rectus muscle is reflected medially exposing the inferior epigastric vessels entering the preperitoneal fat from laterally. All branches are clipped and divided and the vessels are followed cephalad and divided as they branch and enter the body of the rectus usually just below the umbilicus. A tunnel is made under the rectus sheath to the superficial inguinal ring for the artery to emerge from later. Once the artery has been tunneled through, the rectus sheath is closed in the normal fashion.

If the femoral artery is being used then it is exposed just under the inguinal ligament. A jump graft of vein is required. One method is to harvest a length of long

saphenous vein at the ankle for the jump graft. Another method is to expose the long saphenous vein at the thigh for at least 10 cm and attach it end of vein to side of artery to the femoral to create an arterio-venous fistula. The apex of this loop is then divided to form arterial and venous ends for anastomosis.

Both long saphenous veins are isolated at the thigh and all branches preserved in case they are needed. Care must be taken not to grasp the veins directly with dissecting forceps as this will cause intimal damage and increase the likelihood of postoperative venous thrombosis.

If the long saphenous veins are not available (previous radical inguinal dissection, radiotherapy, trauma, etc.) then other veins may be suitable. We have used spermatic cord veins, dorsal vein of the penis, and mid-thigh perforator veins from the long saphenous system with success.

Using an operating microscope, end-to-end anastomoses are performed with 8-0 Nylon interrupted sutures. These are full thickness through the vessel wall. The vessels must not be too long otherwise kinking and obstruction may occur. Once the main vessels are done, the vessel clamps are removed in the following order once the blood pressure is normal: (1) body side of vein, (2) phallus side of vein, (3) phallus side of artery, and then (4) body side of artery. Once flow is established, some vasodilator such as papaverine is administered topically. The minor veins and nerves are now anastomosed.

Nerve preparation and anastomosis

If the dorsal neurovascular bundle of the penis is present then it can be formed into one to two nerve

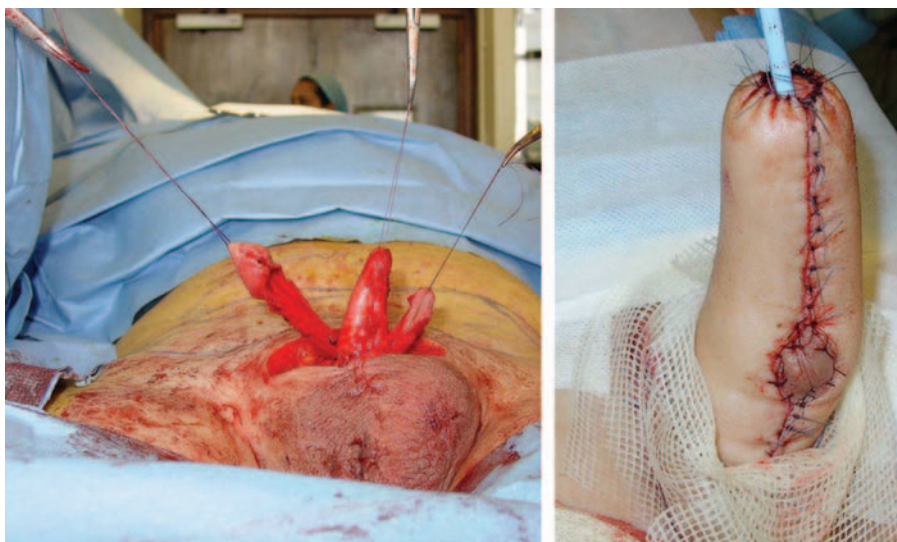


Figure 86.9 Radial artery phalloplasty for micropenis. On the left is the disassembled micropenis. On the right the original glans penis has been incorporated into the ventral suture line for sexual sensation.

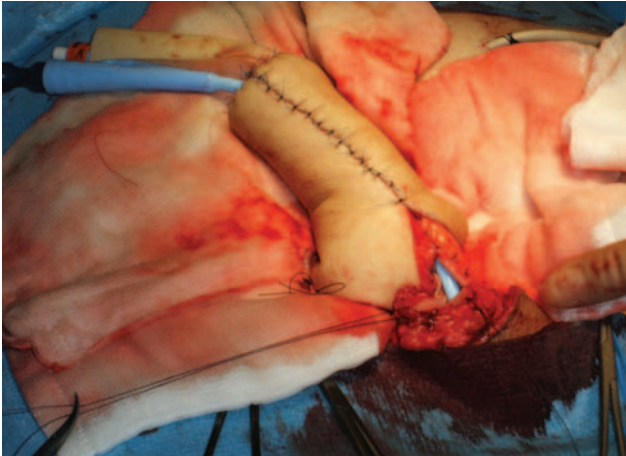


Figure 86.10 Primary urethral anastomosis showing use of V-flap spatulation.

bundles. If the clitoral nerve is to be used, then just one side is used. The clitoral nerve is much larger than the penile nerves and is easily found on the lateral aspect of the body of the clitoris. These can be used to provide erogenous sensation on the phallus. For touch sensation we use the ilioinguinal nerves or genital branch of the genitofemoral nerves. The nerves are anastomosed without tension to the cutaneous nerves in the phallus using three or four epineural sutures with 9-0 or 10-0 Nylon to approximate the nerve bundles. If the nerve ends do not reach comfortably then a short length of vein or other nerve is used to connect the two nerve ends.

Urethra

If there is a pre-existing urethral stump then a primary spatulated urethral anastomosis with seromuscular interrupted 4-0 Vicryl over the 16 Fr catheter is performed (Figure 86.10). In this case a suprapubic catheter must also be inserted to provide additional bladder drainage. If there is no pre-existing urethral stump or the native urethral meatus is some distance away, then the neourethra is attached as low down the perineum as possible. We would spatulate this urethral opening with a U-flap of non-hairy skin. No suprapubic catheter will be needed.

Local flap

The classic example of a local flap phalloplasty is the pubic phalloplasty. A horizontal line is placed at the root of the penile stump, previous position of the penis (if penectomy) or clitoris. This will usually be just below the inferior border of the pubic symphysis. The



Figure 86.11 Skin incision for typical pubic phalloplasty.

flap is measured at 12 cm wide and 12 cm long with another 1–2 cm for the glans (Figure 86.11). If there are transverse scars across the flap then the flap needs to be raised from distal to just inferior to the scar and replaced. If the flap survives, then a completion phalloplasty can be performed 6–12 weeks later. If not, they are offered a radial artery phalloplasty after debriding the necrotic tissue. This kind of phalloplasty does require careful planning, particularly for penile cancer patients as it may be necessary to mark out and incise the flap at the same time as any inguinal node dissections to ensure the blood supply is not compromised later. It may not be appropriate for penile trauma patients particularly if they have had degloving type injuries to the pelvis.

The flap is then incised down to the rectus sheath and lifted. It is important to preserve any draining veins at the inferolateral edge of the flap. The dissection is continued until the flap can be laid flat on the patient's thighs without tension. This ensures the completed phalloplasty is likely to point downwards rather than upwards. The flap is then tubed after careful defatting using 3-0 Nylon sutures (Figure 86.12). The phallus should not feel tight as this causes venous obstruction. If so, further fat needs to be removed. Closure of the defect will require the upper abdominal flap to be mobilized to just above the umbilicus. The umbilicus can be repositioned if needed, although this is rarely necessary. Unless the skin is very loose, the abdominal skin will not reach the phallus. Lateral hip flaps will need to be rotated in to close the defect without tension (Figure 86.13). The subcutaneous space is drained with suction drains and the phallus nursed against the abdomen to improve venous drainage in the postoperative phase. If the abdominal



Figure 86.12 Pubic phalloplasty tubularized leaving a large defect in lower abdominal wall.



Figure 86.14 Gillies phalloplasty in progress showing pedicle transfer on both sides.



Figure 86.13 Closure of pubic phalloplasty abdominal defect using lateral hip flaps rotated inwards and mobilizing upper abdominal skin downwards.

closure is tight the patient may need to be nursed with hips and knees flexed as for an abdominoplasty procedure. Discharge is at about 5 days with suture removal at 3 weeks.

Pedicle

Pedicle phalloplasty is rarely performed unless other methods are not possible. There are three methods. The oldest is the Gilles phalloplasty, followed by the extended groin flap phalloplasty, with the newest method being the anterolateral thigh flap pedicled phalloplasty.

With the Gilles phalloplasty, two parallel incisions 8–10 cm apart (wider if very fat) are made in the hairless love handles area of the lateral abdominal skin. The skin is sutured into a suitcase handle type appearance with wide bases (Figure 86.14). Every 6 weeks the handle can be made a little longer and the cephalad portion of the handle narrowed to polarize the blood supply to the other end. Eventually the cephalad end is disconnected and reattached to the abdominal skin nearer to the pubis with a wide pedicle. The process is repeated until the pedicle is at the desired location in the pubic area. Usually bilateral pedicles are brought down simultaneously. The medial surfaces can then be formed into the distal urethra if needed. This technique involves multiple operations and there is a significant risk of losing the whole pedicle every time there is a pedicle transfer. It is possible to use a tube in tube technique to make the neourethra at the same time. The blood supply of the extended groin flap phalloplasty is based on the superficial circumflex iliac artery from the femoral artery. Lateral to the femoral artery, two long parallel incisions are made extending over the iliac crest. Because the superficial and deep circumflex arteries join, the incision can be extended right round the iliac crest. The width of the flap is at least 12 cm. The distal end is disconnected and the flap elevated towards the groin and tubed with 3-0 Nylon after defatting if needed. The epithelium of the proximal portion of the flap is removed to form a wide and long vascular pedicle. Once this pedicle is mobilized the phallus can be tunneled under the skin to the pubic region retaining the original blood supply (Figure 86.15). The donor site defect can be partially



Figure 86.15 Extended groin flap phalloplasty from left iliac crest.

closed primarily with the rest being covered with split skin graft. It is also possible to insert a tissue expander beforehand to expand the available skin to allow a primary closure. The cosmetic result is poor.

The anterolateral thigh flap phalloplasty can be either a free flap, like the radial artery phalloplasty, or a pedicled flap.⁷ The blood supply is based on the myocutaneous and septocutaneous perforators of the descending branch of the lateral circumflex femoral artery and its venae comitantes. In some patients this pedicle is long enough to be tunneled to the pubic region making this a pedicled flap. Usually for phalloplasty it would be used as a free flap. One of the disadvantages is the thickness of the flap which may require careful defatting.

NEOURETHRAL CONSTRUCTION

Proximal neourethra

The proximal neourethra is the join-up urethroplasty procedure. In gender patients a short anterior vaginal flap is raised. This vaginal flap prevents the jet of urine emerging from the native meatus going straight through a suture line. Lateral inner labial skin flaps are also raised to form the anterolateral walls (Figure 86.16). These are tubed over a 14 or 16Fr catheter with 4-0 Vicryl seromuscular interrupted sutures to the neourethral meatus. A Martius fat pad is prepared and used to cover the anastomotic line prior to skin closure.⁸ In non-gender patients a similar technique is used using non-hairy scrotal skin if available. If the scrotal skin is very hairy then a 4 cm wide onlay graft of buccal mucosa or split

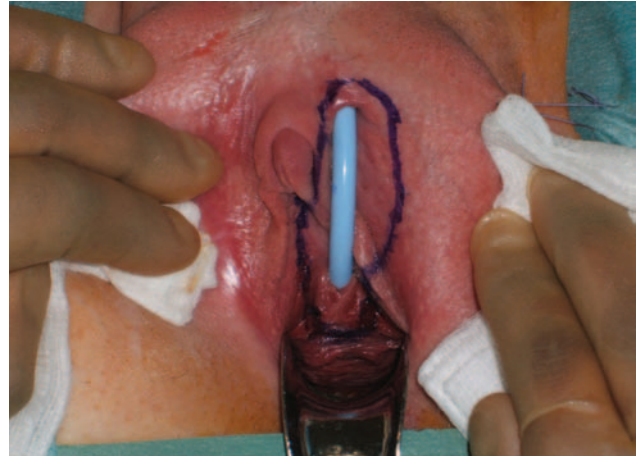


Figure 86.16 Skin markings for join-up urethroplasty in female-to-male transsexual showing anterior vaginal flap and lateral inner labial flaps, leaving clitoris on the outside of the neourethra.

skin graft is placed between the two meatus and tubed over after 3–6 months. A suprapubic catheter is placed as well. The urethral catheter is removed at 7 days and the patient has a trial of voiding at 21 days prior to removal of the suprapubic catheter.

Distal neourethra

If the phallus flap does not incorporate a urethra then there are two choices. The first is to make the urethra after the phalloplasty and the second is to make the urethra before making the phallus. Preconstruction of the urethra is done by wrapping split skin graft 4–5 cm wide around a 40 Fr stent and tunneling this under the skin of the proposed flap. After 3 weeks, the stent is removed and replaced with a smaller stent of at least 16 Fr, preferably bigger. The smaller stent can be removed and washed daily before reinsertion and after 3–6 months, if there are no strictures, the flap can be raised to form the phalloplasty with urethra. Any strictures must be repaired before the flap is lifted. This method can be used for any type of phalloplasty.

If making the phallus first, then the ventral surface of the phallus can be split 3 months later and two long strips of buccal mucosa or split skin graft can be laid. The total width will need to be at least 3 cm. Buccal grafts shrink by about 30% and split skin grafts by up to 50% over 3–6 months so the initial width needs to allow for this. After this length of time the graft can be tubed over a 14 or 16Fr stent. Gender patients also have the option of using the clitoral hood skin and



Figure 86.17 Inverse J-flap from non-hairy labial skin for labial urethroplasty with blood supply based on clitoris.



Figure 86.18 End result of labial urethroplasty with neourethral meatus halfway up shaft of phallus.

inner labial skin as a tubed local flap known as a labial urethroplasty. This will not reach the tip of the phallus so the distal portion of the urethra needs to be made with a free graft as described above. One of the problems with the labial urethroplasty is the increasing incidence of distal stenosis, the longer the flap is, because of ischemia. The skin used must be non-hairy to avoid problems later. The blood supply is based on the clitoris so it is best to keep as much of the flap attached to the clitoral body as possible. The inverted 'J' shaped flap is tubed over a 14 or 16 Fr stent using interrupted 4-0 Vicryl sutures leaving the meatal end spatulated (Figure 86.17). The ventral surface of the phallus is dilated with metal dilators allowing the neourethra to be tunneled up. The meatal opening is fashioned with an inverted U-flap which fits into the spatulated end of the labial neourethra (Figure 86.18). The buccal graft can now be placed distally towards



Figure 86.19 Abdominal skin incisions for a radial artery urethroplasty in a previous pubic phalloplasty. The long strip of full-thickness skin is used to re-graft the forearm donor site.

the tip if needed. The stent is removed after 10–14 days and the patient is taught to self dilate. If there are no strictures, the rest of the urethroplasty can be continued after 3 months.

Yet another method is the radial artery urethroplasty. A 4 cm fasciocutaneous strip based on the radial artery is taken from the volar aspect of the forearm including venae comitantes and the medial cutaneous nerve of the forearm. The defect is closed with full-thickness or split skin graft as appropriate. The abdominal vessels and nerves are prepared in the same fashion as for a radial artery phalloplasty except that the long saphenous vein is rarely needed. A circular button of skin is excised at the tip of the phallus for the meatus. The base of the phallus is opened dorsally to allow access for the microsurgical anastomoses (Figure 86.19). The phallus is dilated with Hegar dilators to size 18. The lower end of the neourethra is placed at an appropriate point in the perineum or if the proximal urethra is nearby, it can be anastomosed directly. A spatulated connection should always be made. Postoperative care is as for a radial artery phalloplasty. Because a nerve anastomosis is always made, this allows sensation in non-sensate phalloplasties.

PROSTHESIS AND COSMESIS

Glans sculpting

Our preferred method of glans sculpting is our modification of the Norfolk technique which is applicable to any type of phalloplasty and is performed at a separate stage. The original Norfolk method involves elevating a



Figure 86.20 Modified Norfolk glans sculpting technique with full-thickness skin graft.



Figure 86.21 Final result of glans sculpting with modified Norfolk technique.

circumferential distally based flap on the phallus and inverting it to form the coronal ridge of the glans (Figure 86.20).⁹ The skin defect is covered by split-thickness skin graft. We prefer full-thickness non-hairy skin graft which is 1–2 cm less in length and narrower than the skin defect. First, this allows the graft to contract and further define the coronal sulcus. Second, the narrowness of the graft allows the pseudoglans to intussuscept onto the shaft further emphasizing the glans. Third, by using a sloping incision and avoiding the ventral area, we create a more natural looking pseudoglans and a frenular area. Finally, the full-thickness graft is much tougher than split-thickness skin and makes penile prosthesis insertion safer (Figure 86.21).

Scrotoplasty

Scrotoplasty is necessary if the scrotum is deficient or missing, as in some trauma and micropenis patients, and all gender patients. For the first two groups, the best option is to insert tissue expanders into the ‘scrotal’ area and inflate progressively over a number of weeks before inserting silicone testicular prosthesis. For the gender patients, if the labia majora are large and roomy, then testicular prostheses can be inserted directly. One problem with this is that the testes sit between the thighs and usually there is insufficient room for them to sit side-by-side. One moves upwards to the base of the phallus and the other downwards to the perianal area. To stop this happening, a combination of V-Y plasty and rotation flaps of the labia majora can be used to create a neoscrotum that is positioned anterior to the thighs to minimize the vertically



Figure 86.22 Scrotoplasty made by mobilizing the lower poles of labia majora and rotating them upwards and medially. The clitoris has been buried.

aligned testes problem (Figure 86.22). Scrotoplasty is best done at the time of the join-up urethroplasty and tissue expanders should be placed either before or after, but not at the same time as, the urethral join-up to minimize infection.

Erection device

A normal penis has the tunica of the corpora cavernosa surrounding the erectile tissue. The corpora cavernosa itself is anchored inferiorly to the inferior ramus of the pubis stretching down towards the ischial tuberosity. A phalloplasty lacks both of these components and they therefore need to be made. For the tunica we use

16 mm wide woven Dacron™ (Vascutek Ltd, United Kingdom) aortic tube graft material. We usually make a Dacron sock and a short Dacron cap, leaving the prosthesis cylinder free to expand in the middle. The Dacron sock is attached to the inferior pubic ramus with non-absorbable Ethibond™ (Ethicon, Livingston, UK) sutures. The Dacron cap gives bulk to the glans and helps prevent erosion. Our preference is for three-piece inflatable prostheses such as the AMS 700CX (American Medical Systems™, American Medical Systems, Minnesota, USA) and occasionally two-piece inflatables such as the AMS Ambicor® (American Medical Systems, Minnesota, USA). Normally one cylinder is sufficient to give decent rigidity unless the phallus is large or there are two corporeal bases to use. With the three-piece prostheses, we routinely insert the reservoir component 3 months beforehand to prevent autoinflation. This is done at the same time as the glans sculpting. As most of the phalloplasty patients will have had at least one suprapubic catheter, we prefer to insert the reservoir through a separate inguinal incision, opening the prevesical space under direct vision. This prevents bladder perforation which can happen with the blind insertion technique. The tubing of the reservoir is capped with a metal plug and placed in the scrotum or neoscrotum as appropriate.^{10,11}

Preoperative preparation is essential. There must be no active skin disease or infection and no urinary tract infection. Full methicillin resistant *Staphylococcus aureus* (MRSA) screening is also performed and treated as needed. The patient is admitted on the day of surgery and has a chlorhexidine gluconate (Prestige Medical Limited, Lancashire, England) shower. The perineal shave is done in theater followed by a 5 minute scrub with povidone-iodine 7.5% (Mölnycre Health Care Ltd, Lance, UK) or Hibiscrub. Once the patient is catheterized the surgical approach depends on the presence of proximal corpora cavernosa. If there are corpora present then a transverse scrotal incision is used, otherwise we use a groin incision starting just above the junction of the groin crease and the inferior pubic ramus extending upwards for about 6 cm along the groin crease.

With the scrotal incision, care must be taken to avoid damaging the urethra which is close by. The corporeal bases are identified and longitudinal corporotomies made. The bases are dilated with Hegar dilators to size 13. The tops of the corpora are punctured with scissors and further dilatation to the tip of the phallus is performed to Hegar size 18. It is important to be careful not to damage the blood supply of the phallus and also not to perforate the neourethra.

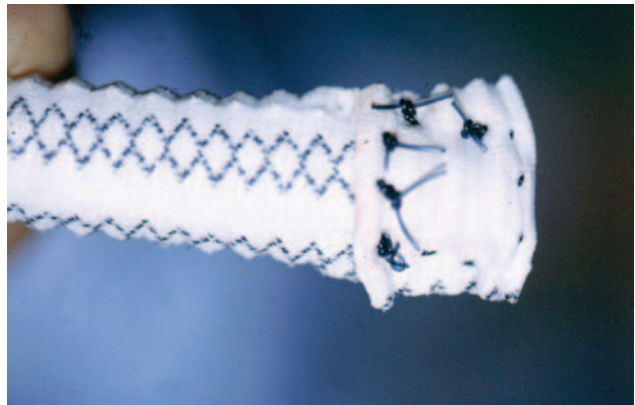


Figure 86.23 Dacron sock with wings for penile prosthesis.

With the groin incision, once the gracilis fascia is visible the neoscrotum is reflected medially to expose the inferior ramus of the pubis as close to the midline as possible. Two Ethibond sutures are placed in the inferior ramus and two at the top of the pubis. The lateral top suture may need to be in the muscle fascia. The phallus is dilated to Hegar size 18 and the distance from tip of phallus to the lower medial Ethibond suture is measured as the cylinder length.

Whilst this is going on, the assistant has been manufacturing the Dacron socks and caps. The lower end of the Dacron tube is incised laterally and the two flaps folded in to form a double-breasted sock. Nylon or Prolene sutures create a sock to fit the base of the cylinder leaving wings on either side to which the Ethibond sutures will be attached. A small hole is made in the sock for the tubing to emerge which anchors the cylinder in place (Figure 86.23). The Dacron cap is carefully sutured to the cylinder tip without puncturing it. If the corporeal bases are present then there is no need for the Dacron socks.

The suture from the cylinder tip is attached to a straight needle and placed in the Furlow device which is passed up the dilated phallus. Once the needle is pushed through the glans the cylinder is pulled up into the phallus and the Ethibond sutures are attached to the wings of the Dacron sock to secure the bottom end. Next, the pump is inserted into the scrotum and attached to the cylinders and reservoir. If a neoscrotum is present, then the testis prosthesis is removed and replaced with the pump and the testis prosthesis inserted on the other side instead. If two cylinders are being used then the second cylinder tubing is passed behind the urethra in gender patients and in front of the urethra in non-gender patients. The wounds are closed in layers with absorbable sutures and suction drains inserted for about



Figure 86.24 Radial artery phalloplasty with single cylinder AMS 700CX inflatable penile prosthesis inflated.

24 hours. The cylinders are left partially inflated for a week. Patients are usually discharged the next day to continue antibiotics for a further week and will return at that time to be fully deflated and to be taught how to use the pump. Sexual intercourse is not permissible until 6–8 weeks have passed to allow the sutures in the pubis to fibrose properly (Figure 86.24).

SUMMARY

Total phallic reconstruction is a challenging but rewarding series of operations with excellent functional and

cosmetic results. Patients must be counselled about complications and the numerous procedures required.

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87 Genital LYMPHEDEMA

W Scott McDougal

Lymphedema of the external genitalia may occur at any age, be transient or persistent, and can be disabling both psychologically and physically. The treatment of this disease is dependent upon its etiology since the cause of the lymphedema usually determines the natural history of the disorder. For some, conservative therapy is sufficient. For others in whom the disorder is disabling and persistent a major reconstructive procedure is usually necessary. Lymphedema is classified according to etiology. This classification is helpful in defining the natural history of the lymphedema so that the appropriate therapeutic modality can be selected. Aspects of diagnosis, conservative treatment, a description of the surgical management, and an evaluation of the effectiveness of various treatment modalities follow. This discussion is based upon our own experience as well as a review of the literature.

ANATOMY OF THE LYMPHATICS

The superficial lymphatic capillary plexuses are thin endothelial-lined vessels, which are found in the dermis of the skin of the external genitalia. The superficial plexuses, which lie beneath the epithelium, do not contain valves and are connected to deeper plexuses in the subcutaneous tissue, which do contain a few valves. These channels coalesce and drain into superficial and deep regional nodes found in the groin and the pelvis. These regional lymph nodes drain to the cisterna chyli in the abdomen, which subsequently drains through the thoracic duct into the subclavian trunk.

CLASSIFICATION

Lymphedema of the external genitalia may be classified according to etiology into those of congenital origin and those due to acquired conditions (Tables 87.1 and 87.2). Congenital lymphedema is expressed at different age periods and may be either sporadic or inherited. The inherited diseases constitute approximately 15% of cases of congenital lymphedema.^{1,2} Lymphedema congenita occurs at birth or shortly thereafter. If it is inherited as an autosomal dominant it is referred to as Milroy's disease.

Table 87.1 Classification of congenital lymphedema of the external genitalia

Age of onset	Sporadic	Inherited
Birth/infancy	Lymphedema congenita	Milroy's disease
Prepubertal/pubertal	Lymphedema praecox	Meigs' disease
Adult onset	Lymphedema tarda	

Table 87.2 Classification of acquired lymphedema of the external genitalia

Neoplastic
Infectious
Granulomatous
Reactive
Disorders of fluid balance
Idiopathic



Figure 87.1 Lymphedema praecox. Note fibrotic appearance of skin and warty excrescences, secondary to chronic lymphedema.

If the lymphedema occurs around the time of puberty and is sporadic, it is called lymphedema praecox (Figure 87.1); however, it is called Meigs' disease if it is inherited – probably as an autosomal dominant but with variable penetrance. Approximately 80% of patients with congenital lymphedema have the onset of their

disease at the time of puberty; the majority of cases are seen in girls near the menarche.¹ If the lymphedema first becomes manifest as an adult it is referred to as lymphedema tarda. Patients with congenital lymphedema rarely have it isolated to the external genitalia but rather have lower extremity involvement which may be symmetric or one extremity may be more involved than the other. Rarely upper extremity lymphedema occurs as well.³ There are varying degrees of associated lymphedema of the external genitalia in these patients. Congenital lymphedema has been associated with Turner's, Noonan's, Klinefelter's, yellow nail and intestinal lymphangiectasis syndromes.¹ Pathologically the lymphatics of the affected tissues are dysplastic and may be categorized into one of three groups: aplastic; hypoplastic, the majority of cases; and hyperplastic.⁴ Malformation and obstruction of the cisterna chyli or thoracic duct has been implicated as the cause of hyperplastic lymphatics in these cases. When the lymphatics are hyperplastic and/or dilated, there may be reflux of chyle into them with weeping of fluid and blister formation on the affected part.⁵

Acquired causes of lymphedema may be divided into neoplastic, infectious, granulomatous, reactive, disorders of fluid balance, and idiopathic. The pathologic process is usually obstructive so that when the affected tissue is examined microscopically, dilated lymphatic channels are found distal to the pathologic process. If the cause is due to neoplasia, the inguinal and/or pelvic nodes are involved with metastatic cancer, most commonly with its origin from the prostate, penis, or bladder. Lymphoma also may be the cause of regional nodal involvement with lymphedema in this region. Infections may be either parasitic or bacterial. Filariasis is perhaps the most common cause of genital edema worldwide. Infestations of the lymphatics are usually due to *Wuchereria bancrofti*, *Brugia malayi*, or *Brugia timori*.⁶ Bacteria responsible for the disorder include *Streptococcus* sp. (the most common cause of lymphangitis), and those responsible for lymphogranuloma venereum, tuberculosis, syphilis, chancroid, and leprosy.⁷ With these infections there may be associated abscesses and sinus formation of the skin and subcutaneous tissue.⁸ If the infection involves the apocrine sweat glands with resultant hidradenitis suppurativa, rarely genital lymphedema may occur. Granulomatous diseases which may be associated with genital lymphedema include sarcoidosis, rheumatoid arthritis, and Crohn's disease.⁹ Invariably, the lymphedema is a secondary manifestation of these diseases.

Reactive causes of lymphedema include trauma, blunt and thermal injuries; venous thrombosis; radiation

therapy; and angioneurotic edema. Angioneurotic scrotal edema occurs most commonly between the ages of 4 and 6, is sudden in onset, may be unilateral or bilateral, is non-tender, and extends onto the perineum and anterior abdominal wall. Occasionally, patients have an eosinophilia. It is self-limited, does not require treatment, and resolves in 2–4 days.¹⁰ Disorders of fluid balance include cardiac and renal failure, fluid overload, and hypoproteinemia. Finally, on rare occasions, the cause cannot be identified either by history or by pathologic examination of the affected tissue. Usually in our experience in these cases, the edema is isolated to a portion of the external genitalia with the other parts having a completely normal appearance. Moreover, the extremities are not involved and there are no associated diseases. We have referred to these cases as idiopathic.

DIAGNOSIS

The differential diagnosis is usually not difficult. Swelling due to lymphedema in the early phase is painless; the tissue is soft and may pit when depressed. As the condition becomes chronic, the skin and subcutaneous tissue may have a woody indurated texture as the tissue becomes fibrotic. When edema fluid of high protein content remains in the subcutaneous tissue for prolonged periods fibrous proliferation occurs. This results in extensive fibrosis of the subcutaneous tissue. The skin may exhibit warty excrescences and blisters, and may weep lymphatic fluid (Figure 87.2). If the cause is infection, subcutaneous abscesses and sinus formation may be apparent. If there is obstruction at the cisterna chyli, chyle reflux with dermal blisters which weep milky fluid (chyle) may occur. One must differentiate lymphedema from Fournier's gangrene, as the latter disease is rapidly progressive and often fatal if not detected early and treated aggressively. Fournier's gangrene has an erythematous and/or a gangrenous appearance to the overlying skin, is acute in onset, and is rapidly progressive. Lymphedema may be acute in onset, however, the overlying skin is initially normal in appearance and the process does not progress over a matter of hours. Venous thrombosis or insufficiency is not generally a difficult diagnosis to exclude since it rarely involves the external genitalia to any significant degree and if chronic is associated with stasis dermatitis.

Complications which occur in the presence of chronic lymphedema include cellulitis, fungal infection, and lymphangiosarcoma. Lymphangiosarcoma of the external genitalia is an extremely rare complication with very few cases having been reported. It is a



Figure 87.2 Close up of genital skin from patient with chronic lymphedema. Note warty excrescences.

highly fatal disease and even with the most aggressive treatment of ablative surgery and radiation therapy, the survival is limited.

TREATMENT

Treatment is dictated by the etiology, associated pathology, and natural history of the disease. If the lymphedema is due to fluid overload or congestive failure, diuretics may be helpful. When the disorder is due to other causes diuretics are not helpful and should not be employed. The response to conservative therapy often depends on whether the pathologic process in the lymphatics can be reversed. Thus, angioneurotic edema, trauma, and first-degree thermal injuries are reversible; local care is all that is necessary. Sarcoidosis has been successfully treated with topical steroids when it is mild and acute.⁹ Mild lymphedema caused by an acute infection such as *Streptococcus* resulting in erysipelas may also be successfully treated with penicillin. On the other hand diseases which result in chronic lymphedema and permanent damage to the lymphatics, infections which result in associated subcutaneous abscesses and sinus formation, and conditions in which the subcutaneous tissue and/or skin has become fibrotic usually require a more aggressive form of therapy.

Infection should be treated and abscesses drained before definitive therapy is instituted. The primary disease if possible should be brought into remission as in selected cases this will improve the edema. When the

lymphedema is persistent and fails conservative measures in patients who are expected to survive their disease at least over the short term, surgical correction of the disorder is indicated. Patients with metastatic disease who are treated with groin and pelvic radiation are particularly prone to lymphedema, however, their survival is generally limited so that major surgical procedures are not indicated and local conservative therapy which makes the patient comfortable is appropriate. These patients do not respond to diuretics or scrotal elevation. Occasionally a suprapubic tube is necessary for comfort measures.

A number of surgical procedures have been described to treat this disorder. The procedures are fundamentally of two types: those that try to improve lymphatic outflow and excisional techniques. A number of methods have been developed in an attempt to improve lymphatic flow from the affected part. These methods include lymphovenous anastomoses, lymphatic grafting, omental flap, mesenteric bridge, and dermal bridge. None of the methods have proven particularly effective over the long term. Indeed, even if successful the reduction in lymphedema is generally modest. If the patient has had cellulitis, lymphangitis, or there is extensive fibrosis, the results are particularly disappointing and therefore these conditions are considered relative contraindications. Lymphovenous anastomoses have been reported to be 50% successful if the etiology is obstructive, but less than 20% successful if the etiology is congenital.^{11,12} An anastomosis of a bisected lymph node to a vein has been reported to improve the lymphedema over the short term but longer follow-up has shown that the anastomosis becomes occluded and fibrotic.¹³ Omental grafts, mesenteric bridges, and dermal bridges have not enjoyed much long-term success and are generally not relevant for the treatment of lymphedema of the external genitalia. Of the above procedures, the most successful are lymphovenous anastomosis in cases where the lymphedema of the external genitalia is caused by obstruction.

The most successful treatments albeit the most drastic are excisional techniques. There are two commonly described methods: subcutaneous tissue removal and preservation of the overlying skin, and removal of all subcutaneous tissue and skin with application of a split-thickness graft. Removing the subcutaneous tissue and preserving overlying skin has been successfully employed in lower extremity lymphedema; however, it has met with less successful results when applied to the external genitalia as only about 30% of patients have an initial satisfactory result. One-third require at least one subsequent revision and 40% eventually require removal

Table 87.3 Results of surgical treatment of lymphedema of the external genitalia (composite from the literature references from which cases were obtained are noted)

	n
<i>Subcutaneous tissue excision with preservation of overlying skin</i> ¹⁴⁻¹⁷	
Satisfactory result	3
Required revision	3
Required excision and split-thickness graft	4
<i>Skin and subcutaneous tissue excised with split-thickness graft</i> ^{7,15,17-21}	
Satisfactory result	24
Required another major procedure	0

of the skin with application of a split-thickness graft (Table 87.3).

SURGICAL TECHNIQUE

Lymphovenous anastomoses

An anastomosis between the dilated lymphatics and adjacent veins has been advocated to treat lymphedema. It is most successful when the etiology is obstructive in nature. The technique involves the injection subdermally of a solution of three parts 1% procaine and one part 1% methylene blue (final concentration of 0.25% methylene blue) 10–15 cm distal to the anticipated incision. Isosulfan blue has also been used. Unfortunately, because the lymphatic flow and/or lymphatics are abnormal, uptake can be slow and visualization of the lymphatics poor. One may need to identify lymphatics by their normal anatomic appearance, i.e. white, tubular structures. In the male the injection is given at the base of the scrotum and in the female in the posterior aspect of the vulva. Bilateral incisions are made at the lateral base of the scrotum and parallel to the medial aspect of the inguinal ligament in the male, and in the upper portion of the vulva extending laterally along the course of the inguinal ligament for 5–7 cm in the female. The superficial lymphatics should not be used but rather those that are in the deeper layer beneath the dermis in the subcutaneous tissue. They are 0.1–0.5 mm in size. Small veins of similar size are identified adjacent to the chosen lymphatics and are sutured end-to-end with 11-0 nylon suture under microscopic guidance. Good results have been

reported using this method but curiously the authors noted that neither the duration of the edema nor the number of anastomoses performed correlated with a successful outcome.^{11,12}

Subcutaneous tissue removal with preservation of the overlying skin

In this procedure all the subcutaneous tissue to the deep fascia of the affected part is removed; the overlying skin is preserved and is reapproximated over the wound. The skin must not have sustained the secondary effects of lymphedema or the disease process, i.e. abscesses, sinuses, scarring, blisters, warty excrescences, and fibrotic dermis. There are two methods by which this technique may be accomplished. The simplest method is to create skin flaps by making a circumferential incision at the corona and connecting it to a vertical incision on the ventral penis which extends to the base of the scrotum. The scrotum is bisected, the testicles and their cords are isolated and all subcutaneous tissue of the scrotum and penis is excised. Redundant skin is excised, lateral skin flaps fashioned, and the scrotum and penis resurfaced.¹⁴ The second technique as described by Feins involves making a transverse incision in the scrotum, everting the scrotal and penile skin, removing the subcutaneous tissue and then returning the skin to its normal anatomic position.²² Sutures loosely secure the skin to the base of the penis. It is important to note that the skin obtains its blood supply from its cephalad and lateral attachments. Care must be taken not to extend the transverse scrotal incision to the lateral aspects of the base of the penis or onto the shaft of the penis. Excellent functional results have been noted with up to 20 years of follow-up. We have found this technique useful in the younger patient whose skin is normal and the lymphedema is of limited extent. The cosmetic result is excellent and the revision rate low when the patients are properly selected.²³

Skin and subcutaneous tissue excision and split-thickness graft

All scrotal, penile, and a portion of suprapubic skin and subcutaneous tissue is excised. This leaves a defect in which the entire perineum, penis, and suprapubic area are devoid of skin and subcutaneous tissue (Figure 87.3). Some advocate preservation of the posterolateral skin of the scrotum at the perineum since it is usually stretched, is rarely involved by the disease and has a collateral vascular and lymphatic supply. When used to

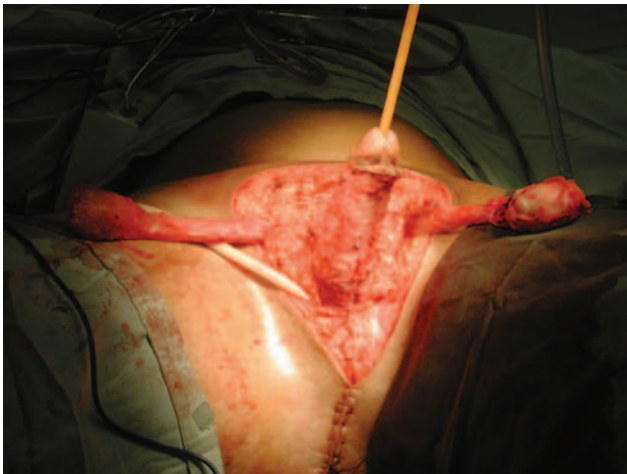


Figure 87.3 Excision of scrotal and penile tissue. Note penile shaft skin is excised to within 2 mm of the corona and all tissue surrounding the testicles has been removed.

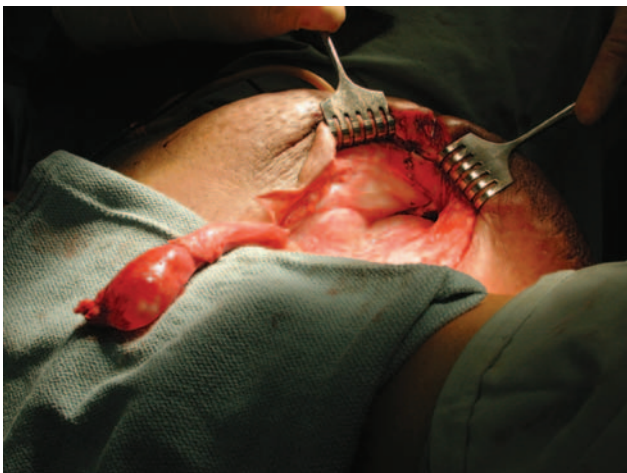


Figure 87.4 The testicles should be identified early in the dissection. The cord structures are first identified in the groin and traced to the testicles in the lymphedematous tissue.

cover the testes, it appears as normal scrotum.^{7,15} Others have found that the lymphedema persists and therefore, have found that it is unwise to preserve it for scrotal coverage.¹⁸ When there is extensive involvement which has been present for prolonged periods, we do not preserve any genital skin as the probability of recurrence is significant. When there is massive involvement it is prudent to place a urethral catheter in the bladder and then to make two incisions, one over each external ring; isolate the testicular cord structures bilaterally; and dissect the cords and testicles from the involved tissue retrograde (Figure 87.4). This should occur early in the operative procedure.²³ It can be exceedingly difficult to palpate the testes beneath the involved tissue; therefore,

care must be taken when one traces the cord to the level of the testes not to injure them. Many patients will have an associated hydrocele of some degree. If it is extensive the tunica vaginalis needs to be removed; it is our preference to routinely remove the tunica vaginalis in all cases. At this juncture all scrotal skin and subcutaneous tissue to the deep fascia of the perineum suprapubic tissue and the penile skin to within 1 mm proximal to the corona and subcutaneous tissue to Buck's fascia is excised. If the skin on the penis is not removed to within 1 mm of the corona, residual penile skin will cause a disfiguring result with the appearance of a doughnut. Some have advocated the use of the inner aspect of the prepuce¹⁹ as it has been suggested that it is not involved with disease. We and others have not found it useful to preserve this tissue. The foreskin should not be left in situ and used to resurface the shaft of the penis retrograde. If this is performed, the foreskin will become edematous and a 'doughnut' deformity will develop²⁴ which will ultimately require revision. Split-thickness graft 0.38 mm is applied to the penis with the seam placed on the dorsum or a spiral configuration may be employed (Figure 87.5A). When contractures occur they generally occur on this seam; Z-plasties may also be performed to minimize contractures. A dorsal contracture is functionally better than a ventral contracture. The split-thickness graft is sutured with 3-0 chromic sutures to the subcorona skin and to the base of the penis, 4-0 chronic suture graft to graft.

The testicles may be covered with either thigh flaps (Figure 87.5B) or split-thickness grafts²⁴ (Figure 87.5A). Thigh flaps are contraindicated if the lymphedematous process is not isolated to the external genitalia and involves the lower extremities. If thigh flaps are employed it is our preference to implant the testes in the thighs, resurface the penis and then reconstruct the scrotum at a later date. When the penile wounds are completely healed the thigh flaps with the testicles are mobilized and the scrotum reconstructed as we have previously described.²⁰ A simpler method to reconstruct the scrotum is to apply split-thickness graft directly to the testes as advocated by McAninch.²⁰ The cord and testes are sutured together in the midline and to the fascia of the perineum. Split-thickness graft meshed 1.5 to 1 is applied to the perineum, testicles, and cord, and sutured to the skin edges with 3-0 silk sutures. A xeroform dressing is placed over the split-thickness graft and cotton wadding soaked in glycerin or mineral oil is placed over the xeroform. The silk sutures, which have been left long, are tied over the cotton wadding to serve as a stent, which holds the graft securely to the underlying fascia. The stent is then removed at 5 days. Alternatively,



Figure 87.5 (A) After removing all involved tissue, the penile shaft is resurfaced with unmeshed split-thickness graft and the scrotum covered with meshed split-thickness graft. (B) The scrotum has been reconstituted with thigh pedicle flaps. This procedure is contraindicated if the lymphedema process involves the lower extremities in which case meshed split-thickness graft (A) is used to reconstitute the scrotum.

a negative pressure vacuum (VAC) dressing may be used in place of stents. Xeroform gauze covers the split-thickness graft on the penis and/or the scrotum. Vacuum-assisted sponges especially designed for this

purpose are cut to size and placed over the xeroform. The wound is covered with a bio-occlusive dressing to provide an airtight seal. A tube placed beneath the VAC dressing is kept at a negative 75 mmHg pressure for 4–6 days.²⁶ This method works well but requires continuous hospitalization whereas the stenting method allows the patient to be treated as an outpatient. The cosmetic result with excision and split-thickness grafting is quite good; however, if the patient has congenital lymphedema, the grafts may initially have a ridged appearance – verrucous nodules of subdermal lymph collections.²³ Over a period of months these gradually subside.

In conclusion, treatment of lymphedema of the genitalia is dictated by etiology. In some cases, conservative measures are all that are indicated and in others radical excision may be in order. If the patients are properly selected the cosmetic and functional results are gratifying.

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88 Management of the non-palpable testicle

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INTRODUCTION

Of the 1% of males diagnosed with cryptorchidism,¹ as many as 20% will have a non-palpable testis.² In these cases, the gonad might be absent, intra-abdominal, or within the inguinal canal (canalicular). Prior to the advent of laparoscopic exploration in 1976, surgical management of the non-palpable testicle consisted of inguinal exploration with extension into the peritoneum if a testis, nubbin, or blind-ending vessels could not be identified.³ The testicle was absent, removed, positioned scrotally, or in the worst case scenario, not located by the surgeon.

PREOPERATIVE ASSESSMENT

At initial evaluation of the patient, a history of palpable gonads, hypospadias, genital surgery, or inguinal herniorrhaphy should be obtained. A careful physical examination (non-threatening in a warm environment with warm lubricant on the groin) is crucial to identify a subtle, but palpable, testicle. Contralateral testicular size should be documented to assess for compensatory hypertrophy.⁴ Bilateral non-palpable testicles represent a distinct subgroup that is discussed later.

DIAGNOSTIC WORK-UP

Any diagnostic test for the non-palpable testicle must reliably determine the presence or absence of gonadal tissue and localize it if present. Radiologic testing, including inguinal/abdominal ultrasound, magnetic resonance imaging (MRI)/magnetic resonance angiography (MRA), herniography, venography, and arteriography, have been shown to have limited value in detection or localization of non-palpable testicles.^{5–7} Although radiographic imaging studies may be useful in certain clinical circumstances, especially the obese child, examination under anesthesia at the time of exploration is generally more cost effective.⁸ Hormonal therapy has promoted testicular descent in some non-palpable cases.⁹ Although rarely therapeutic, this therapy has been applied to patients with bilateral non-palpable testes, and has not been shown to complicate either open or laparoscopic

orchiopexy. Conversely, hormone therapy for the unilateral nonpalpable testicle is probably not cost effective.¹⁰ Surgery, open or laparoscopic, has been the only modality proven to accurately diagnose, localize, and concurrently treat the non-palpable testicle.^{8,11,12}

TIMING OF SURGERY

At birth, the undescended testis has been shown to have normal histology. Although this may continue into the first year of life, delayed germ cell development has been described by 6–8 months of age. These changes are progressive with both light and electron microscopy demonstrating histologic changes consistent with deterioration of the germ cell population detectable by 18 months.¹³ Histology correlates with testicular position, with worst features being seen in higher testicles. However, spontaneous testicular descent has been noted as late as 4–6 months of age. Therefore, in order to allow adequate time for a testis to descend spontaneously while minimizing the risk for irreversible developmental damage, the generally accepted recommendation is to perform orchiopexy at 6–18 months of age. Absolute contraindications to laparoscopic orchiopexy would include cardiac or pulmonary conditions that would be exacerbated by pneumoperitoneum.

Early orchiopexy has been shown to have a positive impact on testicular growth¹⁴ and adult Leydig cell function,¹⁵ supporting these recommendations. Decisions regarding orchiopexy after 2 years of age are based on the risks/benefits of the testicle to the individual. In prepubertal children the usefulness of androgen production must be considered, especially in cases of a solitary testicle. In postpubertal males with a persistently undescended testis, sperm are rarely noted,¹⁶ and the testes are at significant risk for malignant change, leading some authors to recommend orchiectomy in all healthy, postpubertal cryptorchid males under 50 years of age.¹⁷

OPEN SURGICAL MANAGEMENT OF THE NON-PALPABLE TESTICLE

The principles of abdominal exploration and orchiopexy including identification of testicular tissue,

mobilization of the spermatic cord, repair of the associated hernia, and adequate scrotal fixation without tension have essentially remained the same since originally described by Bevan in 1899.¹⁸ Predominantly employed techniques for the intra-abdominal testis prior to the advent of diagnostic laparoscopy included the transabdominal approach, extended inguinal orchiopexy,¹⁹ Fowler-Stephens orchiopexy, two-stage orchiopexy,^{20,21} and testicular autotransplantation.²² It has been supposed that orchiopexy success is related to the preoperative testicular position and loosely defined as satisfactory scrotal position and lack of atrophy. The need for impeccable technique to protect the vasculature to the testis and obtain sufficient length for orchiopexy is indisputable, and becomes more pronounced the more proximal the testis. The early assumption that orchiopexy is a largely successful operation and failures are few and far between was likely due to the more common practice of inguinal orchiopexy for the distal undescended testicle. In a meta-analysis of open orchiopexy techniques, Docimo reported success rates by type of procedure (inguinal 89%, Fowler-Stephens 67%, staged Fowler-Stephens 77%, transabdominal 81%, two-stage 73%, microvascular 84%) and concluded that the high failure rates left significant room for improvement.²³

LAPAROSCOPIC MANAGEMENT OF THE NON-PALPABLE TESTICLE

Diagnostic laparoscopy

The principal goal of diagnostic laparoscopy is to determine the presence of non-palpable testicular tissue. Intraoperatively, the mobility of the testicle, its vas deferens, and its vascular supply are assessed to determine if the tissue is amenable to orchiopexy or if the testicle is better removed. The indications/goals of diagnostic and therapeutic laparoscopy are identical to the goals of open surgical management, i.e. to improve fertility, identify and relocate the testicle to the scrotum for easier examination, ablate the associated inguinal hernia, and prevent testicular torsion. Historically, laparotomy was performed to localize an intra-abdominal testis or diagnose blind-ending vessels if cord vessels were not observed on initial inguinal exploration. This was most often accomplished with a high inguinal (i.e. Jones incision) or Pfannenstiel incision. It is now standard practice at most centers of excellence to proceed with diagnostic laparoscopy when the testicle is non-palpable.

Initially described by Cortesi et al in 1976,²⁴ diagnostic laparoscopy has become the gold standard for the evaluation and treatment of the non-palpable testicle. In six early series,^{25–30} laparoscopy identified 42 testicles in 86 patients after prior negative open exploration. Recent studies report that blind-ending cord structures or an intra-abdominal testis are found during laparoscopic evaluation of non-palpable testis between 31 and 83% of the time.^{28,31–36} Barqawi et al reviewed 27 patients who had undergone previous inguinal exploration and identified a viable canalicular or intra-abdominal testicle in 67%.²⁸ Cisek et al reported that laparoscopic findings precluded unnecessary abdominal exploration in 13% of cases and that the typical surgical incision for inguinal exploration would have left the surgeon compromised in 66% of cases compared with the approach optimized as a result of laparoscopic testicular localization.⁸ In many of these patients, diagnostic laparoscopy can eliminate the need for further open exploration or facilitate open or laparoscopic orchiopexy.

Alternative strategies in the evaluation of non-palpable testes have been described. To reduce the number of unnecessary intra-abdominal laparoscopic procedures, Kanemoto et al suggested initial inguinal exploration followed by trans-inguinal laparoscopy.³⁷ In 22 patients with a hypertrophied unilateral palpable testis, Belman et al reported that scrotal exploration prior to laparoscopic evaluation identified an atrophic testicular remnant in 91% of patients.³⁸ Schlee et al described a technique in which they proceeded first with laparoscopic evaluation of the inguinal canal to avoid unnecessary open exploration.³⁹ The decision to proceed with an inguinal or laparoscopic abdominal exploration first depends on the surgeon's certainty on physical examination and is still currently a source for debate. However, the evidence clearly suggests that if an initial open inguinal exploration is inconclusive, laparoscopic exploration should be the next step in the diagnosis and treatment of the non-palpable testis. Our current protocol is to perform examination under anesthesia. If any tissue suggestive of a scrotal nubbin is felt, then open scrotal exploration is performed. If this examination is negative or inconclusive, only then do we perform laparoscopic exploration.

Laparoscopic orchiopexy

Laparoscopic techniques have been applied to the therapy of intra-abdominal testes as an extension of diagnosis. The impetus for development of these techniques

Table 88.1 Laparoscopic orchiopexy

Study	N	Mean operative time (min)	Testicular atrophy (%)	Unsatisfactory scrotal position
Baker et al, 2001 ²⁹	310	124	2* 22† 10‡	1* 7† 2‡
Radmayr et al, 2003 ³⁴	57	49* 38/53‡ (by stage)	0* 7‡	NA
Samadi et al, 2003 ⁴⁸	197	NA	0* 7‡	9* 0‡
El-Anany et al, 2006 ⁴⁹	93	NA	0* 4‡	3* 3.5‡

* Primary laparoscopic.

† One-stage Fowler-Stephens.

‡ Two-stage Fowler-Stephens.

has been the difficulty of achieving successful open orchiopexy for the high undescended testis.²³ There have been many technical descriptions of laparoscopic orchiopexy with similar success rates; our approach is described later in this text. Lindgren et al reported a 93% success rate in the treatment of 44 non-palpable testes in 36 patients with no evidence of testicular atrophy.⁴⁰ Initial laparoscopic orchiopexy series, although viewed as promising, were criticized for originating from high volume centers with increased laparoscopic experience and low patient numbers.^{40–47} To address this issue, in a large multi-institutional analysis, Baker et al reported excellent success rates superior to those of historical open orchiopexy and no significant difference in success or complication rates between low and high volume centers.²⁹

Parents or guardians are made aware of the approximate 8–25% risk of testicular atrophy associated with performing an orchiopexy regardless of operative technique.²³ Operating on an intra-abdominal testicle may carry the highest risk for failure (25%). Recent long-term data, however, suggest that atrophy rates following laparoscopic orchiopexy can be as low as 7% at 6-year follow-up whether or not a staged Fowler-Stephens procedure is utilized (Table 88.1).^{29,34,48,49} The goal of laparoscopic orchiopexy is to adequately lengthen the testicular vessels and vas deferens to enable relocation of the testicle to the orthotopic scrotal position. Ultimate 'success' of laparoscopic orchiopexy will therefore be measured by maintenance of the testicle in proper scrotal position without evidence of atrophy. Equally important is avoiding the associated complications inherent to this laparoscopic procedure. In light of this, it is critical to know the different steps that will maximize successful outcomes.

In the open inguinal approach, the groin is first explored. If a testicular remnant is found (hemosiderin deposit or atrophic testicle), it is removed and the procedure is terminated.⁵⁰ If the groin exploration is negative, the incision is extended, the peritoneum is entered, and exploration for an intra-abdominal testis is carried out. Open exploration is still a viable option in managing the non-palpable testis, especially among urologic surgeons without laparoscopic experience. One recent single-surgeon open orchiopexy series reported success rates of 100% and 98% for open primary orchiopexy and staged Fowler-Stephens, respectively,⁵¹ though these success rates are higher than generally reported. It can be argued that a laparoscopic approach to the non-palpable testicle can result in a primary or Fowler-Stephens orchiopexy⁵² with the advantage of less morbidity.⁵³ Cost, formerly higher for laparoscopic approaches, can no longer be used as a bias against initial laparoscopic exploration when planning to manage the non-palpable testicle.⁵⁴

The decision to perform a single-stage procedure leaving the vessels intact, or to perform a one- or two-stage Fowler-Stephens procedure is challenging and no specific set of criteria has been determined. Baker et al reported the incidence of testicular atrophy after primary laparoscopic (2.2%), one-stage Fowler-Stephens (22%), and two-stage Fowler-Stephens (10%) orchiopexy.²⁹ Some centers advocate universal two-stage procedures whereas others try to be more selective. Intraoperatively measuring the distance between the testis and the internal ring, observation of the cord anatomy, or the ability of the intra-abdominal testicle to reach the opposite inguinal ring can be helpful.⁵⁵ Laparoscopy has also been used as an adjunct to microvascular testicular autotransplantation.⁵⁶ Compared

with open orchiopexy, the early data show that laparoscopic orchiopexy is a successful approach with low risk in the management of the non-palpable undescended testicle.

LAPAROSCOPIC TECHNIQUE FOR THE NON-PALPABLE TESTICLE

Immediate considerations prior to commencing with the procedure include re-examination, patient positioning, and starting an ongoing dialog with the anesthesia team. A difficult intraoffice examination may have yielded a false result. Indeed, in approximately 18% of boys a previously non-palpable testis will be palpable when the child is examined under anesthesia.⁸ In this regard, the child should be completely relaxed anesthesiologically and an orogastric tube should be placed. In the instance of a unilateral non-palpable testicle, assessment of the size and length of the contralateral testicle may be helpful in determining if indeed the intra-abdominal testicle is present. A contralateral palpable testicle length exceeding 2 cm and an average volume of more than 2 ml for example, have been cited as being predictive of monorchia in over 90% of cases,^{38,57} though not reliable enough to forego exploration.

Inhaled nitrogen dioxide should be avoided in order to avoid bowel distention and hence maximize visualization in the abdomen. When starting with a laparoscopic approach, the arms are tucked and the legs are placed in the frog leg position. The child is then secured to the table with 4 inch tape placed without tension over the chest and legs. Securing the child to the table permits the placement of the child in Trendelenburg or rolled positions. When prepping and draping, an open procedure should be planned for and draped accordingly. In the sterile field an appropriately sized Foley catheter is placed. Figure 88.1 demonstrates the preferred set-up and trocar placement for performing a laparoscopic orchiopexy.

Blind access for pneumoperitoneum with a Veress needle or trocar is less commonly used in the pediatric population as an overly compliant abdomen may increase the risk of injury to intra-abdominal structures. It is our preference to use the Bailez technique for open access,⁵⁸ modified to employ the use of a radially dilating trocar.⁵⁹ In our current technique a 2-0 Vicryl suture is first placed in the umbilicus to provide continual anterior tension. A 3 mm hidden infraumbilical incision is made in the skin and scissors then used at an approximate 15–20° angle to cut through the umbilical fascia into the underlying adherent peritoneum. Alternatively,



Figure 88.1 Preferred set-up for a left single-stage laparoscopic orchiopexy. A 5 mm radial dilating trocar is placed at the umbilicus. Two 3 mm working ports are placed lateral to the rectus muscles just inferior to the umbilicus. Care is taken to avoid injury to the epigastric vessels. In the event that either a single- or two-stage Fowler-Stephens procedure is performed, a 5 mm trocar would be used on the contralateral side to accommodate a 5 mm clip applicator to ligate the testicular vessels. A 10 mm scrotal port is placed in the final stage of the case when the mobilized intra-abdominal testicle is delivered into the scrotum.

the rectus fascia and underlying peritoneum may be entered sharply at 90° under direct vision.

For the umbilical camera port, we utilize a 5 mm radially dilating trocar to accommodate a 5 mm camera with a 0° lens.⁶⁰ The child is placed in Trendelenburg position and the abdomen is insufflated at 1–2 liters/minute to a pressure of 10–12 cmH₂O. After inspecting the underlying bowel for injury the pelvis is examined. If an instrument is needed to aid in the inspection, only then is a 3 mm port placed on the ipsilateral side lateral to the rectus and just caudal to the umbilicus. An atraumatic 3 mm instrument may then be used to sweep bowel cephalad. Placement of a 5 mm trocar on the contralateral side (lateral to the rectus and just caudal to the umbilicus) is reserved for use of a 5 mm clip applicator. Clinical circumstances in which this would be necessary include if an atrophic nubbin is to be excised, or if a viable testicle is found far from the internal ring and a staged Fowler-Stephens orchiopexy is to be performed.

In the case of a unilateral undescended testicle, the internal ring of the descended testicle is examined first to gain an appreciation of the anatomy. Possible findings on inspecting the affected side of the ‘non-palpable’ testicle include blind-ending testicular vessels, cord structures entering the internal ring, and intra-abdominal testis.

Blind-ending testicular vessels

The finding of blind-ending gonadal vessels is evidence of a 'vanishing' testicle. This is considered to be a result of in utero testicular torsion that is either an intra-abdominal or intrascrotal event. Vessels will have a 'horse tail' appearance that diverge, do not exit the internal ring, and do not supply obvious testicular tissue (Figure 88.2). If found during exploration, no further investigation is needed and the procedure is terminated. It has been argued, however, that fixation of the contralateral testicle might be considered at this point to safeguard against testicular torsion of the solitary testicle. Bellinger, for example, described the presence of a bell-clapper deformity in 83% of children with a vanishing testis whose contralateral scrotum was explored.⁶¹ Clinical torsion of the solitary testis is such a rarely reported event, however, that the risk of exposure and fixation of an otherwise healthy testis may be as significant as the risk of eventual torsion. There is no consensus on the need for contralateral fixation in this situation.

The sole finding of a blind-ending vas during laparoscopy, is insufficient to conclude the absence of testicular tissue; it is assumed that gonadal dysjunction has occurred. Further cephalad inspection toward the aortic origin of the gonadal vessels is then necessary. Intra-abdominal blind-ending vessels were found in 9.8% of boys with non-palpable testes in one series.⁸

When there is a unilateral undescended testicle, examination of the contralateral testicle may aid in predicting the presence or absence of the non-palpable gonad. Hypertrophy of the normal descended testicle, for example, may be more likely in the case of monorchia. Testicular hypertrophy may be predictive of monorchia in 90% of cases and has been defined as a testis volume greater than 2 ml and/or a testicular length greater than 1.8 cm.^{38,57} These findings may also support the concept of primary scrotal exploration in the child who has an empty hemiscrotum and a hypertrophied descended testicle. If a remnant is not found on scrotal exploration, laparoscopic exploration should follow.

Cord structures entering the internal ring

Laparoscopically, cord structures may be visualized entering a closed internal ring or a patent processus vaginalis (open ring) (Figure 88.3). In either scenario further exploration may be warranted to determine what lies distally along the line of testicular descent.⁶² In the

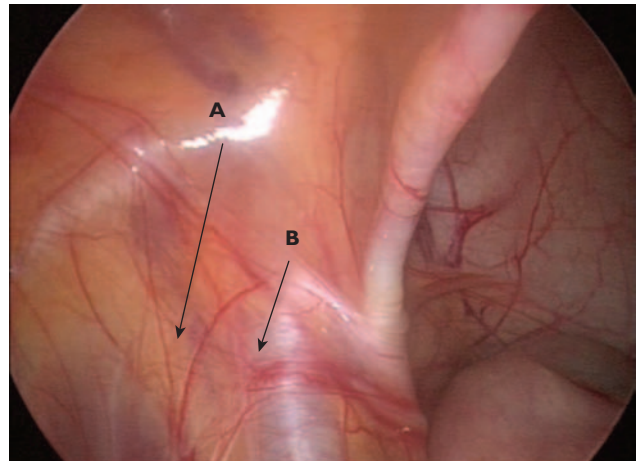


Figure 88.2 Finding blind ending and divergent testicular vessels. (A) Evidence of a vanishing testicle. The sole finding of a blind ending vas (B) is insufficient evidence to conclude that there is absence of ipsilateral testicular tissue.

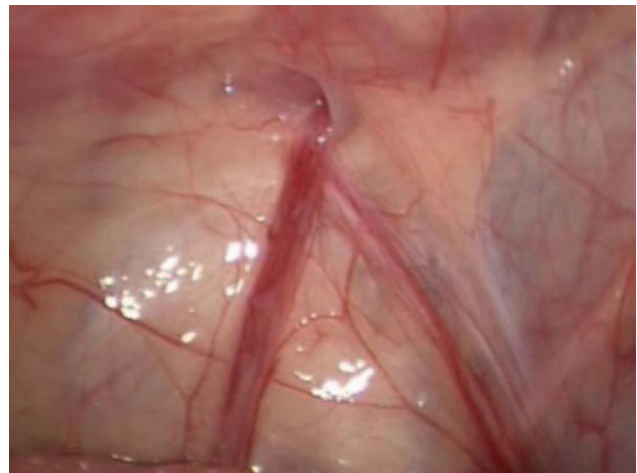


Figure 88.3 Laparoscopic view of a left patent processus vaginalis (hernia) with normal cord structures exiting the internal rings. Left groin exploration revealed a high viable intracanalicular testicle. Inguinal orchiopexy with hernia sac ligation was performed.

instance of a closed internal ring, a groin or scrotal exploration may be performed (Figure 88.4). If a patent processus vaginalis is present the laparoscope may be used to inspect the inguinal canal antegrade. Alternatively, gentle manual retrograde pressure can be placed over the inguinal canal in an attempt to push groin contents (viable testicle vs nubbin) intra-abdominally. A single-stage laparoscopic or open orchiopexy may be carried out when a viable testicle is encountered (described below). In the instance of a nubbin or testicular remnant, laparoscopic orchiectomy is performed.

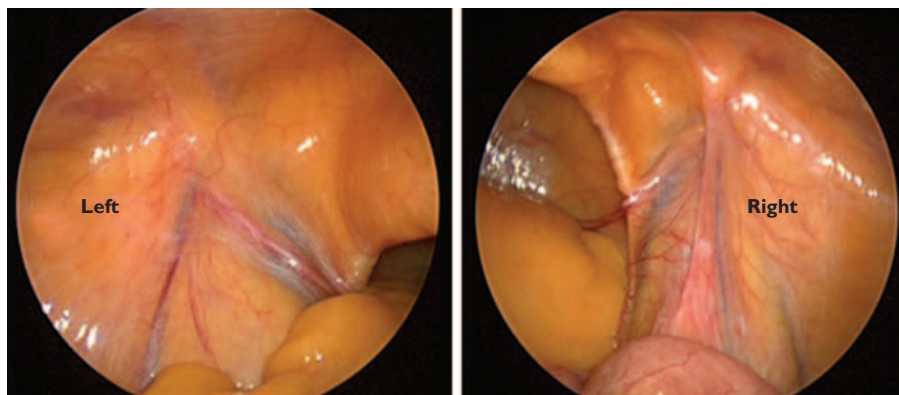


Figure 88.4 Bilateral closed processus vaginalis with normal cord structures exiting the internal rings. This morbidly obese 8-year-old boy underwent exploratory laparoscopy for a 'non-palpable' left testicle. The findings on diagnostic laparoscopy of cord structures exiting the left internal ring led to a left groin exploration. A high viable intracanalicular testicle was found and open orchiopexy was performed.

This is accomplished by either clipping and dividing the cord contents or using a 5 mm instrument designed to seal and divide smaller vessels (i.e. Ligasure or harmonic scalpel). The specimen is grasped and removed from the contralateral 5 mm port. This incision can be widened as needed by spreading with any clamp while under direct vision from the camera port.

Intra-abdominal testis

There are three minimally invasive reconstructive options to address an intra-abdominal testicle: primary laparoscopic orchiopexy, one-stage laparoscopic Fowler-Stephens orchiopexy, and two-stage laparoscopic Fowler-Stephens orchiopexy. In a multi-institutional analysis, success rates for these procedures have been quoted at 97.2%, 74.1%, and 87.9%, respectively.²⁹ Interestingly, these results show an advantage over the open approach when outcomes from an earlier study are compared. For example, a literature review and analysis by Docimo reported success rates of 81.3%, 66.7%, and 76.8% for primary orchiopexy, one-stage Fowler-Stephens, and two-stage Fowler-Stephens orchidopexy, respectively.²³ Results of laparoscopic orchiopexy therefore compare favorably with open approaches for cryptorchidism.⁴⁰

Laparoscopic orchiectomy is reserved for an intra-abdominal non-viable testis (iatrophic nubbin) or a testis that cannot be brought into the scrotum owing to an extreme ectopic location (retrovesical, pararenal, pararectal) limiting blood supply length. Older children (over 4 years of age) found to have an intra-abdominal testis are better served with a laparoscopic orchiectomy provided the contralateral testicle is intrascrotal. Although an intra-abdominal testicle may remain hormonally active indefinitely, spermatogenic potential tends to decline after 18 months.

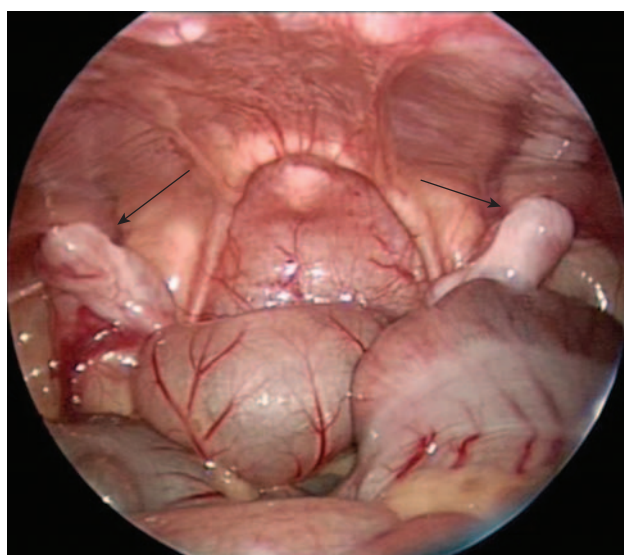


Figure 88.5 Bilateral intra-abdominal 'peeping' testicles at the internal rings in a 6-month-old boy with non-palpable gonads. Bilateral single-stage laparoscopic orchiopexies were performed.

The initial measured distance of the testicle from the internal ring will determine which laparoscopic approach should be utilized and is therefore a predictor of success rates. 'Peeping testes' or those located in close proximity to the internal ring (<2 cm) can usually be mobilized into the scrotum in a single stage without dividing the testicular vessels (Figure 88.5). It is important to counsel parents that although an overall 7% atrophy rate is expected, intra-abdominal ectopic testes and those located more than 2 cm from the internal ring are at increased risk for surgical failure. In light of this, if an intra-abdominal testicle is found at a significant distance from the internal ring and is thought to be amenable to a two-stage Fowler-Stephens orchiopexy, the testicular vessels are doubly clipped (Figure 88.6). A laparoscopic

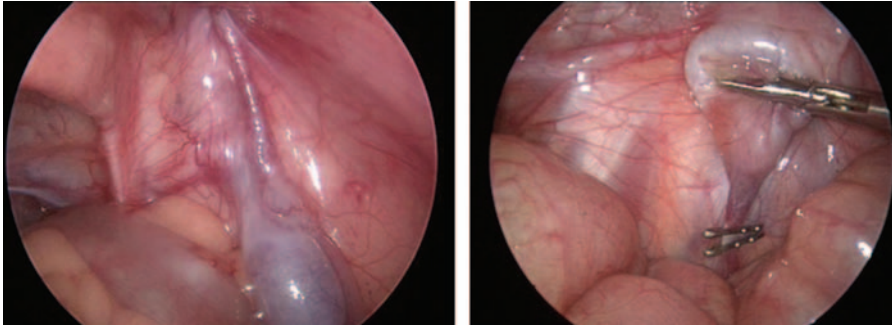


Figure 88.6 A right intra-abdominal testicle in a 9-month-old boy was found more than 2 cm from the internal ring. The testicular vessels were clipped in the first stage of a two-stage Fowler-Stephens reconstruction. Note that clips are applied without dissecting the peritoneal attachments free from the vessels.

second-stage Fowler-Stephens orchiopexy will be performed approximately 6 months later when collateral blood flow from the deferential artery has matured.

In 1991, Bloom reported using laparoscopy to ligate the testicular vessels in the first stage of a Fowler-Stephens approach.⁴⁶ Jordan and Winslow further advanced the role of laparoscopy as a therapeutic modality when they reported the first laparoscopic orchiopexy in 1992.⁴⁵ There have been many subtle variations described for performing this procedure. Herein our preferred laparoscopic technique is described. Figure 88.1 should be referred to as our preferred operative set-up when either a primary laparoscopic orchiopexy or a second-stage Fowler-Stephens laparoscopic orchiopexy is performed. It should be remembered that a 5 mm trocar must be used at the port site lateral to the rectus (contralateral to operative site) if a stapler or vascular sealing device is going to be used.

SINGLE-STAGE LAPAROSCOPIC ORCHIOPEXY

Establishing a peritoneal pedicle flap

Following abdominal access, insufflation, and additional trocar placement, as described above, attention is focused on the ipsilateral testicle and internal ring. Figure 88.7 demonstrates the surgical 'map' needed to mobilize a triangular flap of peritoneum demarcated by the testicular vessels laterally and vas deferens medially. The preliminary goal is to create two continuous peritoneotomies parallel to the testicular vessels and vas in order to mobilize the testicle on a well vascularized peritoneal pedicle.

The first survey requires evaluation of the testicle, epididymis, and extent of vasal descent distally into the inguinal canal. It is critical from the onset to define the gubernacular attachments and identify a long-looping vas, if present. Scissors are used in the preliminary

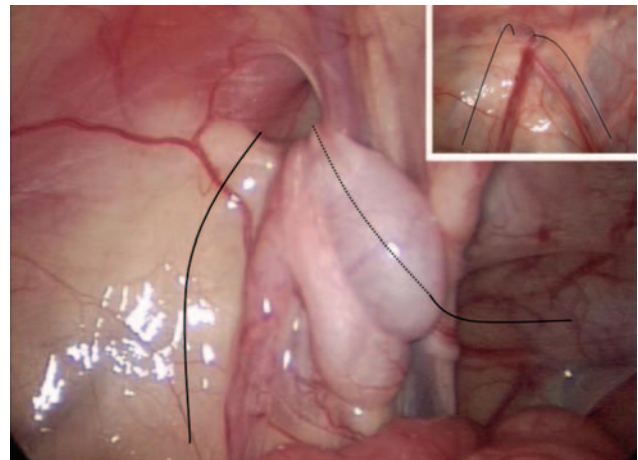


Figure 88.7 A left intra-abdominal testicle in an 8-month-old boy at the internal ring. The dark lines represent where peritoneotomies are made parallel to the testicular vessels (lateral) and vas deferens (medial) in order to mobilize the testicle on a vascularized peritoneal pedicle flap. The insert shows the same landmarks when a non-palpable intra-canalicular testicle is milked into the abdomen and then mobilized via laparoscopic orchiopexy.

dissection. Care must be taken not to activate cautery in too close proximity to the vessels and vas. The first peritoneotomy is made lateral to the testicular vessels at the most proximal position. The incision is directed toward the internal ring. Often after the first incision, pneumoperitoneum will diffuse into the plane between the peritoneum and pelvic side wall. In this regard, carbon dioxide can facilitate isolation of the peritoneum to be dissected.

The second line of dissection will again begin at the level of the internal ring distally but will parallel the vas medially. Care is taken not to injure the iliac vessels and ureter that lie beneath the vas. It is also critical that dissection is not performed within the distal triangular area enclosed by the gonadal vessels and vas (Figure 88.8). Critical collateral microvasculature within this flap will flow from the vasal artery to the

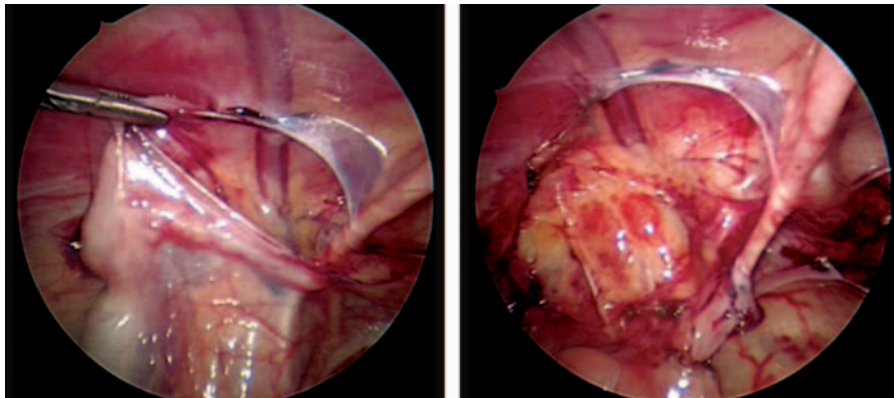


Figure 88.8 After lateral mobilization, medial dissection follows the course of the vas deferens (left). Collateral paravasal blood supply to the testicle is visualized. Cephalad traction following release of the distal gubernacular attachments (right) demonstrates the extent of the peritoneal flap and clarifies the boundaries where the neoinguinal hiatus is to be created between the inferior epigastric vessels and the medial umbilical ligament.

testicle and should be maintained if possible. This is especially relevant if a single-stage Fowler-Stephens orchiopexy is performed; dividing the testicular vessels and interrupting collateral blood flow will invariably lead to testicular atrophy.⁶³ Widely mobilizing the peritoneal flap laterally and medially leaves only the distal gubernacular attachments. A window is created distally allowing the gubernaculum to be divided while visualizing the course of the vas deferens. An indication that dissection has maximized the flap length is that the testicle can reach the contralateral internal ring without tension. The ipsilateral ring is not closed since there is not an increased risk for a clinically significant hernia to develop. The patent processus is ablated by the peritoneal incisions, division of the gubernaculum, and, if necessary, incision of the anterior peritoneum. Subsequently, the peritoneum obliterates the previously patent tract.

Creating a neoinguinal hiatus and testicular delivery into the scrotum

Various methods to deliver the testicle into the scrotum have been described. It is our belief that the testis may be most safely and effectively delivered to the scrotum using 2 or 3 mm instruments and a radially dilating trocar system.⁶⁴ A 12 mm ipsilateral scrotal incision is first made and a subdartos pouch is created. A 2 mm laparoscopic grasper is placed through the ipsilateral 3 mm lateral trocar directed toward the scrotal incision. Care is taken to place the instrument over the pubis and between the medial umbilical ligament and epigastric vessels. The surgeon's free hand should palpate the pubic area and scrotal incision to ensure the instrument is being guided over the pubis and through the scrotal incision. After the instrument is passed through the scrotum the Foley catheter is checked for hematuria. A bladder injury, which is very

rare, would most likely occur during this step of the procedure. Proper placement of the instrument in the position described above should minimize the risk of this complication occurring (Figure 88.9). The step sheath is then passed onto the end of the 2 or 3 mm instrument *ex vivo* and brought through the scrotum. The 5 or 10 mm trocar obturator, depending on the size of the testicle, is then inserted creating the neoinguinal hiatus. A locking grasper is introduced into the abdomen through the scrotal trocar, the testicle is grasped at the gubernaculum, and then delivered into the scrotum (Figure 88.10). It is imperative for the surgeon to personally monitor the tension on the cord during scrotal delivery so the vessels are not avulsed.

Gaining additional cord length and securing the testicle

Delivering the testicle into the scrotum provides the traction and assistance of what we have termed 'a third arm'. If there is tension and/or additional length is needed, further dissection can be carried out laterally and cephalad toward the kidney. In most instances the cord length will still be inadequate and additional maneuvers are required. An option at this point is to divide the peritoneum overlying the testicular vessels to provide extra cord length and release any remaining tension (Figure 88.11). If incising the peritoneum has not helped, consideration can be given to dividing the testicular vessels, therefore performing a one-stage Fowler-Stephens orchiopexy. The contralateral 3 mm port must be upsized to a 5 mm port in order to accommodate a clip applier. Consideration must be given to the higher risk of testicular atrophy prior to performing a one-stage Fowler-Stephens maneuver.

When the testicle lies tension free in the scrotum the orchiopexy can be completed (Figure 88.12). The testicle is harnessed in the dartos pouch and the scrotal skin

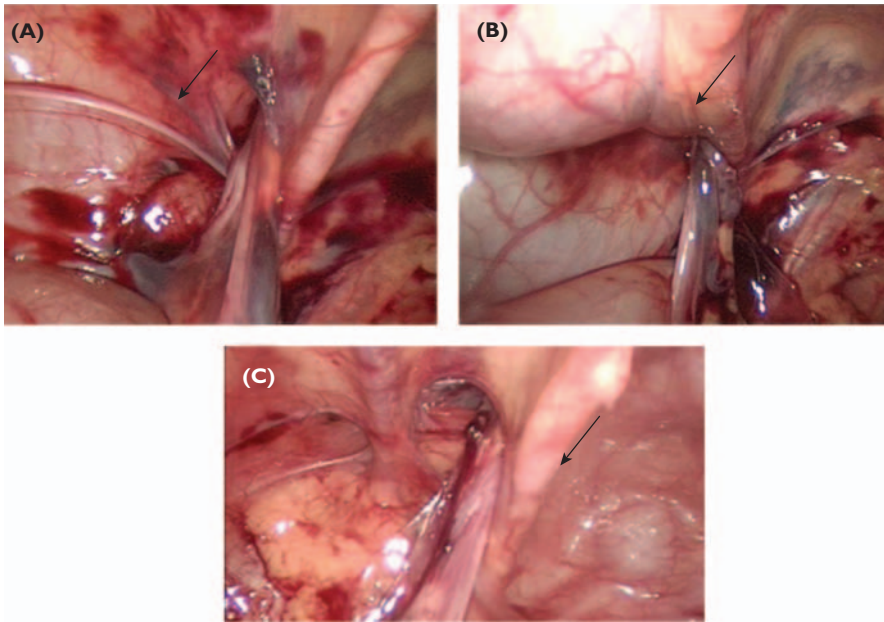


Figure 88.9 During delivery of the testicle into the scrotum, the bladder edge (arrows) is at increased risk for perforation. The risk is increased if the neoinguinal hiatus is not created anterior to the pubis and lateral to the medial umbilical ligament. Following delivery of the testicle medial to the ligament in a right laparoscopic orchiopexy there was concern that the bladder was perforated (A). Filling the bladder demonstrated no evidence of a leak (B). After delivery of the testicle through a 10mm scrotal trocar in the final stage of a left laparoscopic orchiopexy there was little concern of a bladder injury. The neohiatus was created in a plane lateral to the medial umbilical ligament and medial to the epigastric vessels (C).

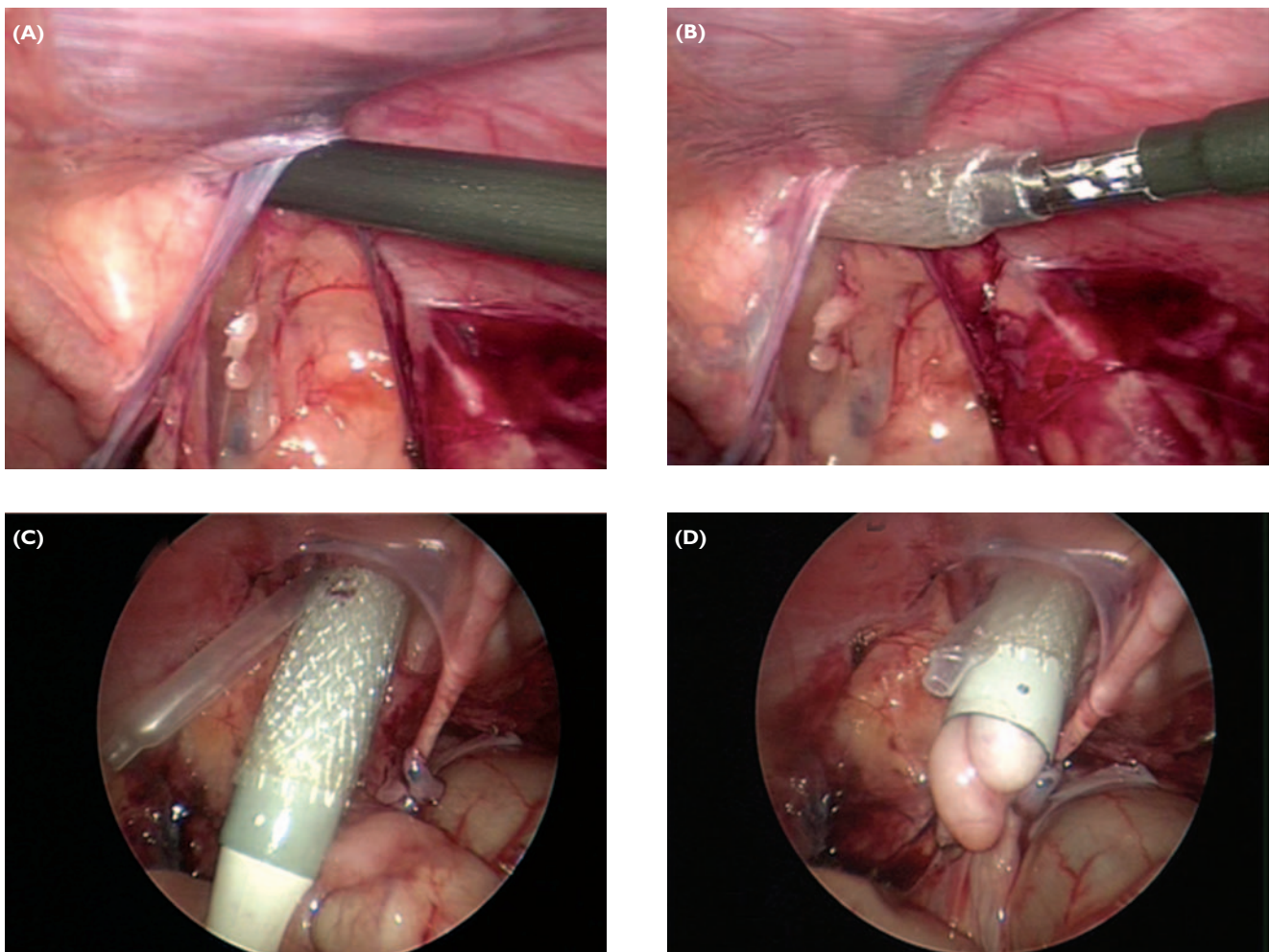


Figure 88.10 Delivering the testicle into the scrotum requires developing a neohiatus (A)–(C) to facilitate passage of the testicle, epididymis, and cord structures into the scrotum without resistance. This technique minimizes the risk of an avulsion injury (D).

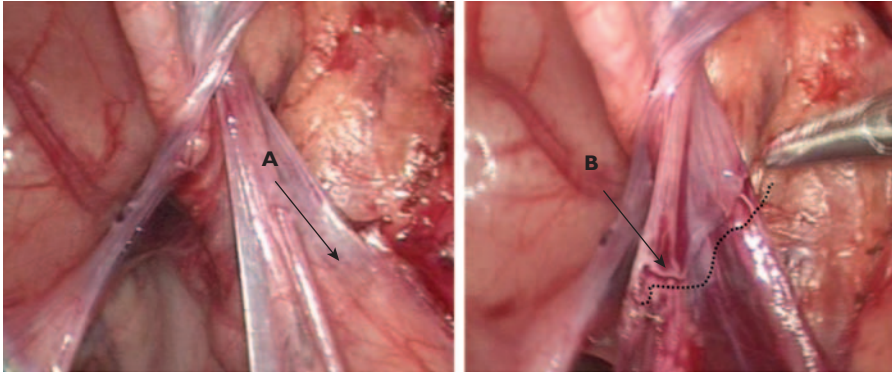


Figure 88.11 Delivering the testicle into the scrotum provides the traction and assistance of 'a third arm'. If there is tension and/or additional length is needed, further dissection can be carried out laterally and cephalad. The peritoneum overlying the testicular vessels (A) may also be divided (B) to release tension and provide extra cord length.

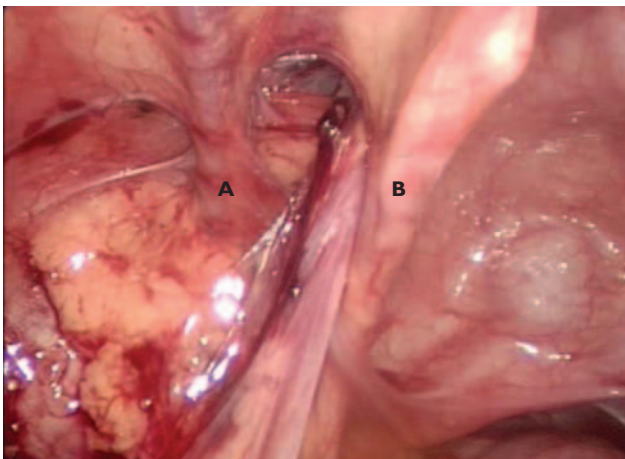


Figure 88.12 Antegrade view of a left neoinguinal hiatus created between the inferior epigastric vessels (A) and the medial umbilical ligament (B). The testicle is fixed to the scrotum after maximal length on the cord has been reached without residual tension.

is closed by any of the preferred technique(s) utilized by the surgeon.

Closure and exiting the abdomen

The abdomen is surveyed a final time and the pneumoperitoneum pressure is lowered. Any occult bleeding should be identified and addressed. While maintaining pneumoperitoneum, the two lateral ports are removed sequentially and inspected for bleeding. The fascial layers of these trocar sites are closed with 2-0 Vicryl sutures through the fascia. The laparoscopic view is maintained on the port sites during closure to ensure that it is airtight and free of any intra-abdominal contents (i.e. bowel or omentum). Through the umbilical port the pneumoperitoneum is evacuated. Larger tidal volumes given by the anesthesiologist and mild abdominal pressure

help with the expulsion of carbon dioxide. The umbilical trocar and camera are removed while inspecting for bleeding. Final fascial stitches are placed in the umbilical port, the skin is closed and dressings are applied.

SECOND-STAGE FOWLER-STEPHENS

As a general rule, the further the intra-abdominal testicle lies from the internal ring (i.e. more than 2 cm) the higher the likelihood that a staged procedure is necessary. Staging the procedure will enable delivery of the testicle into the scrotum without tension and at a decreased risk for atrophy. This may be accomplished laparoscopically by using a 5 mm applier through the contralateral port. After 6 months, the second stage is performed exactly as described above with the addition of dividing the previously clipped testicular vessels, and maintaining a 'tongue' of peritoneum overlying the vas deferens and its associated vessels.

BILATERAL NON-PALPABLE TESTES AND LAPAROSCOPIC ORCHIOPEXY

Bilateral non-palpable testicles in a newborn should raise the suspicion of an intersex condition, especially with coincidental genital ambiguity (i.e. proximal hypospadias). Other possibilities include bilateral anorchia or bilateral intra-abdominal testis. It is urgent to institute a work-up to rule out life threatening intersex conditions such as congenital adrenal hyperplasia (CAH). Once an intersex disorder has been excluded, endocrine studies including a human chorionic gonadotropin (hCG) stimulation test and/or serum Müllerian inhibitory substance (MIS) will be useful in differentiating anorchia from bilateral cryptorchidism.⁶⁵ Regardless of such laboratory findings, however, exploratory laparoscopy will be needed for a gonadal biopsy, gonadectomy, or orchiopexy (Figure 88.13).

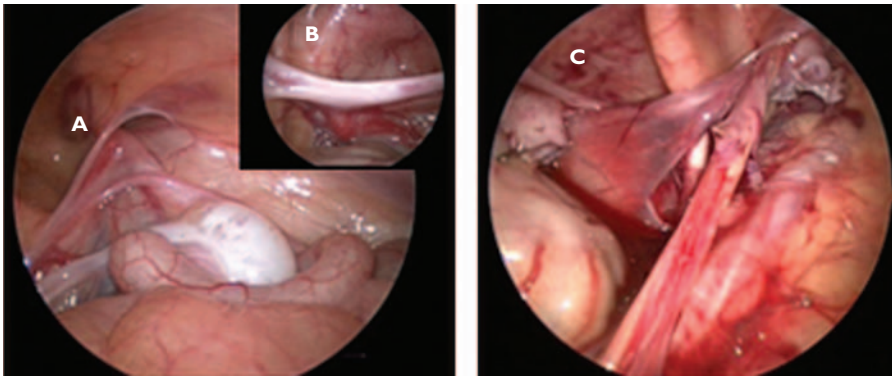


Figure 88.13 An 8-month-old XY phenotypic male with bilateral undescended testicles and Müllerian inhibiting substance (MIS) deficiency. MIS hormone level was 0.1 ng/ml (normal 48–83). Diagnostic laparoscopy revealed bilateral intra-abdominal testicles (A) with Müllerian (uterus) and Wolffian (vas) structures intimately associated (B). Left laparoscopic orchiopexy was performed, aided by releasing the contralateral round ligament (C).

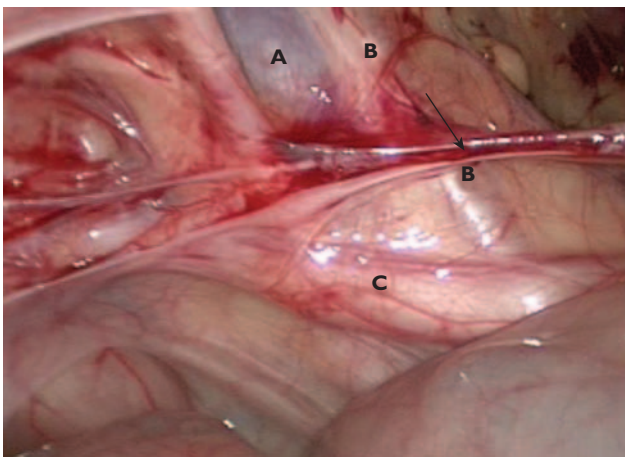


Figure 88.14 Pelvic view during a right laparoscopic orchiopexy. During medial mobilization of the vas deferens the cord structures (arrow) are held cranially and laterally. Care must be taken not to injure the iliac vein (A), iliac artery (B), and or ureter (C) that lie immediately posterior to the mobilized peritoneal flap.

COMPLICATIONS

The number of complications associated with laparoscopic orchiopexy compares quite favorably with that of an open approach. In a large multi-institutional review, Baker reported a major complication rate of 3.0% and a minor complication rate of 2.0%.²⁹ Major complications that have been reported include acute testicular atrophy, bowel perforation,⁴⁷ cecal volvulus, vascular injury,⁶⁶ bladder perforation,⁶⁷ ileus, laceration of the vas,³² testicular vessel avulsion,⁶⁸ and wound dehiscence/infection. In addition, there are the potential complications that are inherent to any laparoscopic procedure that are important to recognize (i.e. pneumothorax and trocar site hernia⁶⁹).

The prevention of complications associated with laparoscopy starts with proper positioning and padding to reduce the risk of neuromuscular injuries. Although

injuries are less likely to occur with pelvic laparoscopy, extremes in table positioning are often necessary. Close attention to placement of straps and/or tape and adequate padding should limit positioning-related injuries.

Complications related to access are a common concern. Indeed, the most frequent identifiable cause of complications within pediatric laparoscopy has been the method used for abdominal access. The pediatric abdomen is very compliant and limited in space. For this reason, open peritoneal access has been associated with fewer complications than when a Veress needle is used.⁶⁶ As previously mentioned, we prefer to gain access using an open Bailez technique. Regardless of the access technique used, preperitoneal insufflation may still occur. This complication can readily be identified when there is characteristically high opening pressure at low volumes. Additional sharp dissection and entry into the peritoneal cavity followed by repositioning of the trocar is necessary if this occurs. Prior to placing additional working ports, areas vulnerable to trocar injuries must be mapped and noted with the laparoscope. Due to great abdominal wall compliance, the epigastric vessels, iliac vessels, and bowel all come into close proximity to access trajectories. Immediate inspection of these loci before and after port placement is mandatory.

Surgical planning and an appreciation for the anatomic landmarks within the pelvis will aid in avoiding complications. During testicular mobilization, care must be taken to avoid injury to the vas, testicular, femoral, and iliac vessels, and the ureter. When mobilizing the vas on the medial aspect of the peritoneal flap these structures lie directly posterior and medial (Figure 88.14). In general, complications can be limited by careful intra-abdominal mobilization, using cautery in short bursts, and execution of meticulous technique. The laparoscopic approach helps to facilitate this by allowing extensive and high retroperitoneal mobilization of the testicular vessels in an atraumatic manner.

CONCLUSIONS

Laparoscopy has evolved from a diagnostic procedure to a surgical treatment of choice when managing the intra-abdominal testicle. The type of procedure used is reflective of the intra-abdominal positioning of the testicle and its distance from the internal ring. Success rates for these techniques are comparable with or better than those reported in open series. Maintaining a mobilized testicle on a wide peritoneal flap free from tension is the key to maintaining scrotal position and minimizing the risk of testicular atrophy. Although there is a learning curve associated with this minimally invasive technique, it is surmountable. Laparoscopy has become the gold standard technique for diagnosis and reconstruction of the intra-abdominal testis.

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89 Vasovasostomy and vasoepididymostomy

Edmund S Sabanegh Jr

Vasovasostomy and vasoepididymostomy are surgical procedures designed to bypass an obstruction in the male genital tract. The safety and efficacy of vasectomy for birth control has fueled a growing demand for vasectomy reversal, as up to 5% of men will eventually request a restoration of fertility due to changing life circumstances such as remarriage, death of a child, or a change in plans. Although vasectomy reversal is usually undertaken to restore fertility, on occasion it is requested to relieve pain, such as that elicited by postvasectomy pain syndrome. While the vast majority of vasovasostomy and vasoepididymostomy procedures are to reverse intentional obstruction, other indications for these procedures include correction of epididymal or vasal obstructions due to genital infections from such organisms as *Neisseria gonorrhoeae*, *Chlamydia* species or *Mycoplasma tuberculosis*. Additionally, vasal or epididymal obstruction can result from iatrogenic injuries related to inguinal or scrotal surgery, especially during the early childhood years.

REVIEW OF RELEVANT ANATOMY

To understand the surgical bypass procedures needed to restore seminal tract patency, it is critical to have an understanding of the anatomy and physiology of the efferent ductal system. Mature spermatozoa are produced by the seminiferous tubules and released into the tubular lumen. This drains into the rete testis, an area within the posterior mediastinum of the testis where a network of anastomosing ducts consolidates into the efferent ducts. The efferent ducts merge into the head of the epididymis to mark the beginning of the epididymal tubule.

The epididymal tubule is a highly convoluted thin-walled structure that measures approximately 5–6 m in length from end to end. Grossly, the epididymis is divided into three regions: the head or caput, midbody or corpus, and tail or cauda. At the termination of the cauda epididymis, the tubule emerges as the vas deferens. The vas deferens has some marked convolutions at its most proximal end, but becomes a straight structure. The vas deferens has a thick muscular wall which is vital to the propulsion of the vasal contents toward

the ampulla of the vas on ejaculation. The vas deferens travels out of the scrotum, through the inguinal rings, crosses in front of the ureter and behind the medial umbilical ligament to traverse behind the bladder where it becomes more dilated to form the ampulla of the vas. A narrow segment, the ejaculatory duct, enters the prostate and terminates in the prostatic urethra.

While knowledge of the exact function of the epididymis remains incomplete, research has shown that transit through the proximal portion is critical to sperm maturation. It has been well established that vasal anastomosis to the cauda epididymis confers lower conception rates than anastomosis to the more distal two-thirds of the epididymis. The cauda epididymis does not appear to have a significant role in sperm development but does seem to function as an area of sperm storage before ejaculation.

DESCRIPTION OF OPERATIVE PROCEDURES

General operative considerations

Vasectomy reversals are typically performed as an ambulatory day surgery. In cases where the vasal obstruction interval is short (less than 10 years), it is reasonable to perform the surgery under local anesthesia with sedation since it is unlikely to require a vasoepididymal anastomosis. Typically, the skin incisions are injected with 1% xylocaine. Once the vas is isolated, 0.25% bupivacaine is injected into the vasal sheath to allow an extended duration of anesthesia. In the setting where a vasoepididymostomy is contemplated, or in patients whose level of anxiety may make a local anesthetic procedure problematic, a general or continuous spinal anesthetic is preferred.

Careful attention must be paid to the patient's intraoperative position since uncomplicated vasovasotomies may require 2–3 hours of operative time and vasoepididymostomies often take up to 4 hours. All pressure points should be carefully padded and the patient's arms should be abducted at a less than 45° angle to minimize the risk of a brachial plexus

injury. Sequential compression hose are placed on both calves for deep venous thrombosis prevention.

The surgical incision is centered over the prior vasectomy site. I prefer to use longitudinal incisions since these allow access to a longer section of the vas deferens which is especially important when long segments are missing or in repeat reconstructions where vasal mobilization can be difficult. Typically, the incisions are 1–2 cm in length and only the vas ends are delivered through the skin incision. If a vasoepididymostomy will be required or if a long vasal defect is appreciated, a longer skin incision is made to allow delivery of the testis.

On occasion, additional procedures may be performed in conjunction with the vasectomy reversal. Testis biopsy is not usually required except under rare conditions when men have had a potentially fertility-impacting event since the vasectomy, such as chemotherapy, radiation therapy, or scrotal trauma. Similarly, concurrent vasogram is not routinely undertaken unless there is a high suspicion of an inguinal or retroperitoneal vasal obstruction. These patients have typically undergone pediatric inguinal surgery and may have had difficulty causing a conception even before their vasectomy. In the event a vasogram is required, a 24 gauge blunt-tipped angiocatheter is placed into the distal end of the vas at the vasectomy site. A volume of 5–10 ml of 50% radiocontrast is injected and fluoroscopy or a plain radiograph is obtained to demonstrate patency with free flow into the urethra. Vasal patency can also be confirmed by passing a 2-0 prolene suture into the distal end of the vas and assessing the length of free passage.

With respect to the performance of a successful anastomosis, two general operative principles must be followed. First, the anastomosis, whether a vasovasostomy or vasoepididymostomy, must have sufficient mobilization of the vas deferens to allow a tension-free connection. The vas ends should be mobilized with their vascular pedicle to minimize the risk of ischemic stricture of the anastomosis. Second, the anastomosis should be watertight. Small amounts of extravasation in the postoperative period allow sperm granuloma formation which can distract the anastomosis, resulting in eventual stenosis.

Choice of reconstruction: vasovasostomy versus vasoepididymostomy

The choice of reconstruction depends on a number of factors including the duration of time since the

vasectomy (obstructive interval), the quality of the fluid from the proximal vas at the time of surgery, and the surgeon's microsurgical experience. Epididymal obstruction is relatively rare within 4 years of a vasectomy but occurs on one or both sides in up to 62% of patients who are at least 15 years from their vasectomy.¹ Proximal vasal fluid quality also guides the surgeon toward a choice of anastomosis. Of patients with motile sperm in their proximal vas fluid 94% had a return of sperm in their ejaculate after vasovasostomy, compared with only 60% who had no sperm in the fluid.² The absence of fluid or thick, viscous, paste-like fluid is widely supported as indicative of an epididymal obstruction and such patients require a vasoepididymostomy for their reconstruction.

Our laboratory used multivariate analysis to create a linear regression algorithm based on time since vasectomy and patient age to predict if a vasoepididymostomy would be required in vasectomy reversal.³ The equation for the vasoepididymostomy prediction score was $(\text{age} \times 0.31) + (\text{obstructive interval} \times 0.94)$. If the score was greater than 20, there was a significant probability that a vasoepididymostomy would be required on one or both sides based on a retrospective analysis of 483 patients. The score was intentionally set for a 100% sensitivity (that is, patients with a score less than 20 could virtually always be treated with a vasovasostomy) to allow urologists who were not comfortable performing the technically demanding vasoepididymostomy to identify this population preoperatively and refer to someone who has the appropriate experience with this procedure. This model was subsequently validated in a multicenter retrospective and prospective review of 345 vasectomy reversal patients.⁴

Vasoepididymostomy remains a challenging surgical procedure, even for the experienced microsurgeon. Meticulous surgical technique and a high degree of magnification are required for a precise anastomosis of the vas, with a luminal diameter of 300–400 μm , to an epididymal tubule with its luminal diameter of 150–250 μm .

Vasovasostomy reconstructive techniques

The procedure begins with a small scrotal incision as described above with blunt and sharp dissection in the region of the prior vasectomy site to dissect the vas with its pedicle from surrounding tissue (Figure 89.1A). Bipolar or hand-held thermal cautery units are used

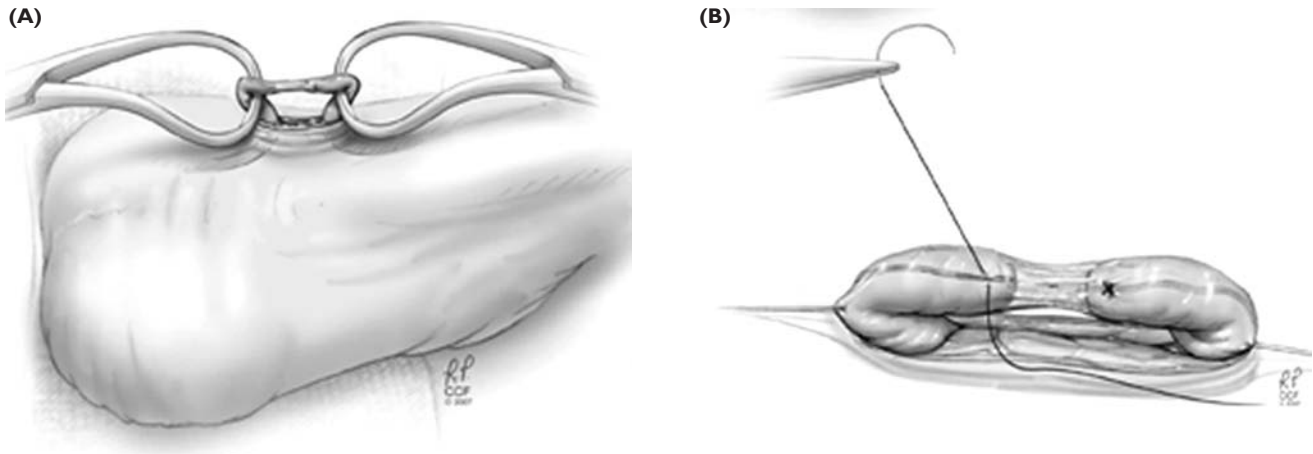


Figure 89.1 Preparation of the vas deferens. (A) Isolation of the prior vasectomy site with delivery through the skin incision. (B) Vasal holding sutures with ligation of the vascular pedicle adjacent to intended anastomosis sites. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

to obtain hemostasis while minimizing surrounding cautery injury. The vasal pedicles are ligated with interrupted 6-0 nylon sutures immediately adjacent to the intended vasal anastomotic sites (Figure 89.1B). After the vas has been sufficiently mobilized, the prior vasectomy site is resected. It is critical that the vas be resected back to normal healthy tissue to minimize the chance of postoperative stenosis. Fluid from the proximal vas is examined under the microscope. While the presence of spermatozoa is associated with the best prognosis for future fertility, copious clear fluid without spermatozoa also portends a good outcome. If motile sperm are identified, this fluid can be cryopreserved for possible in vitro fertilization in the event of anastomotic failure if the couple has expressed a desire for this.

Vasovasostomy may be performed under loupe or microscope magnification. While macrosurgical vasovasostomy techniques which do not use optical magnification have been described in the past, these procedures suffer from higher rates of failure and are now of a historic nature. Two of the most widely accepted techniques, the modified one-layer and the formal two-layer vasal anastomosis are described below. Both techniques offer comparable success rates² in experienced hands, although it is clear that the formal two-layer anastomosis offers more precise mucosal alignment.

Modified one-layer vasovasostomy

The modified one-layer anastomosis was popularized by Schmidt⁵ and can be performed under either loupe

or microscope magnification. The healthy vasal ends are brought into opposition in preparation for the anastomosis. Some surgeons place the ends of the vas in an approximating clamp to facilitate the anastomosis. It has been our practice to place a 6-0 prolene suture in the periadvential tissue at the base of each vas (Figure 89.1B). This is secured to the operative drape in a fashion to allow performance of a tension-free anastomosis.

The anastomosis is performed by placing four to six 9-0 nylon sutures through the full thickness of each vasal end (Figure 89.2A and B). Next, additional 9-0 nylon sutures are placed in the seromuscular tissue between each of the full-thickness sutures (Figure 89.2C). It is crucial that these outer layer sutures do not enter the lumen as they could inadvertently catch the back wall of the lumen and obstruct the anastomosis.

Formal two-layer vasovasostomy

This anastomosis, first popularized by Silber,⁶ requires the use of a microscope and should be performed by surgeons skilled in microsurgery. The vasal ends are prepared in a similar fashion as described for the modified one-layer vasovasostomy. Two 9-0 nylon sutures are placed in the serosa to secure the vasal ends at the 5 and 7 o'clock positions (Figure 89.3A). Six to eight 10-0 nylon sutures are placed and tied to approximate the mucosal edges of the vasal ends (Figure 89.3B). Because of the difference in luminal diameter between the dilated proximal vas lumen and the smaller distal vas lumen, sutures should be spaced to allow careful alignment of

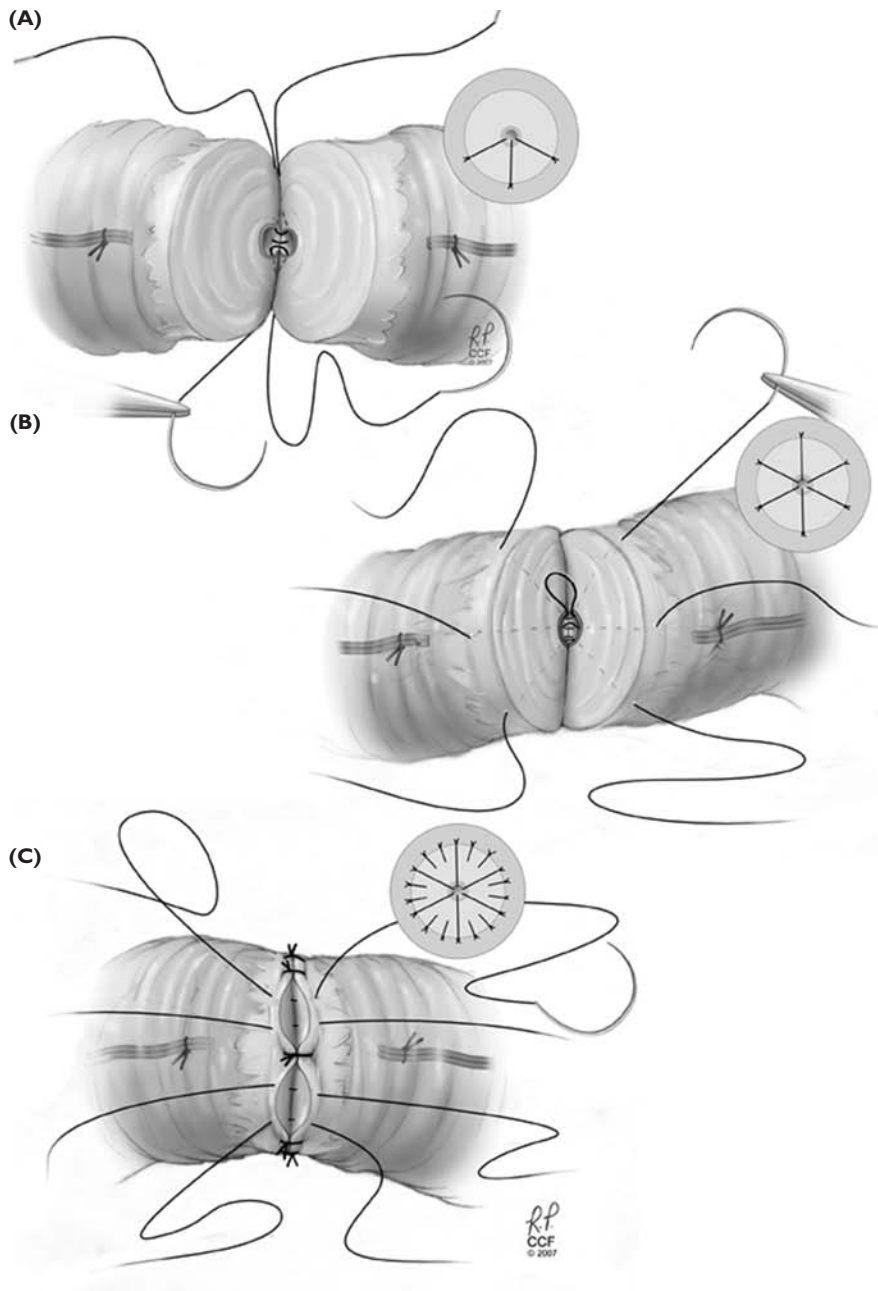


Figure 89.2 Modified one-layer vasa-vasostomy. (A) Placement of three full-thickness 9-0 nylon sutures in the posterior aspect of the ends of the vas deferens. (B) Additional three full-thickness 9-0 nylon sutures in the anterior aspect. (C) Completion of the anastomosis with interrupted 9-0 nylon seromuscular sutures between the full-thickness stitches. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

the mucosa to avoid bunching of the mucosal edges. Suture ends should be cut closely to the knot to minimize protrusion of the suture tails into the anastomosis. Finally, six to eight additional 9-0 nylon sutures are placed in the serosa over the mucosal anastomosis to complete the technique (Figure 89.3C).

Other vasa-vasostomy anastomotic techniques

A variety of other anastomotic techniques have been utilized with varying degrees of success. While a

comprehensive review is beyond the scope of this chapter, several techniques are worthy of mention. The techniques seek to shorten operative time and experience requirements for the surgeon while maintaining or improving upon surgical outcomes.

With the growing interest in application of robotic assisted surgical procedures, it is of no surprise that this technology has been applied to microsurgery.⁷ Preliminary results in animal models suggest that despite a significant learning curve, robotic technology may someday have a role in vasal reconstruction since

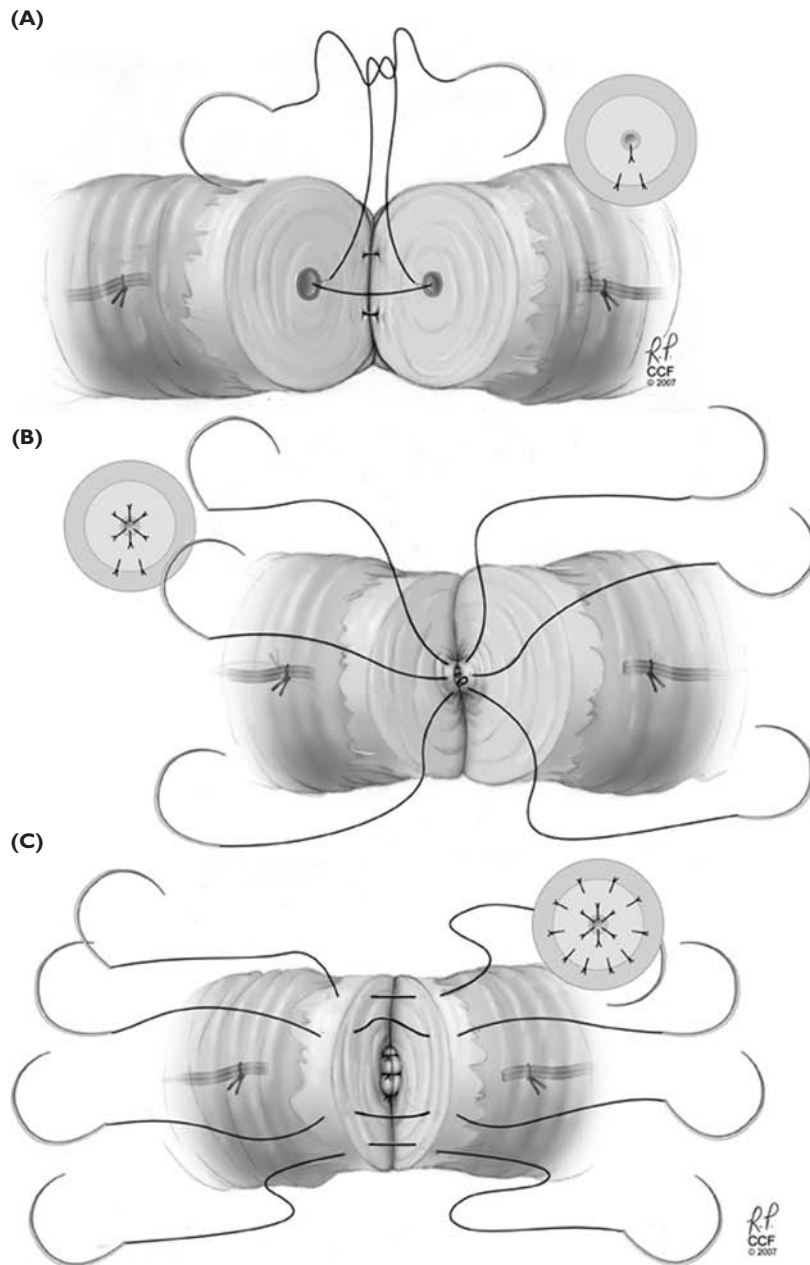


Figure 89.3 Formal two-layer vasovasostomy (inset diagrams show inner and outer suture locations). (A) Two 9-0 nylon seromuscular sutures have been placed in 5 and 7 o'clock positions of vasal ends and tied. The first 10-0 nylon mucosal suture has been placed posteriorly, note double armed suture which facilitates precise in-to-out placement of mucosal sutures. (B) Additional 10-0 nylon mucosal sutures placed in anterior aspect. (C) Anastomosis is completed with outer 9-0 nylon seromuscular sutures with tied mucosal sutures visible deep to suture placement. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

it may help surgeons overcome some of the unique challenges of microsurgery (hand tremor, management of fine suture/instruments).

In addition, research efforts have focused on the development of methods to produce vasal adhesion while minimizing suture placement. The carbon dioxide laser has been successfully used to produce spot thermal welding of the vasal ends after placement of several microsurgical sutures.⁸ Tissue adhesives such as fibrin glue have also shown promising

results while requiring the placement of minimal traditional microsutures.⁹

Vasovasostomy results

It can be difficult to compare the surgical outcomes from vasovasostomy series due to failure to standardize obstructive intervals, coexisting female factor infertility, and differences in surgical algorithms in choice of vasovasostomy and vasoepididymostomy. The largest

Table 89.1 Vasovasostomy outcomes²

Obstructive Interval (years)	Patency (%)	Pregnancy (%)
<3	97	76
3–8	88	53
9–14	79	44
≥15	71	30

and most comprehensive look at vasovasostomy outcomes was by the Vasovasostomy Study Group² which provided a multicenter review of outcomes for 1469 men. They established the clear relationship between obstructive intervals and success (Table 89.1).

Vasoepididymostomy reconstructive techniques

Unlike the vasovasostomy, vasoepididymostomy often will require 3–4 hours and may require extensive scrotal dissection to perform an adhesiolysis of the scrotal contents and obtain the necessary vasal length. This usually necessitates a general or continuous epidural anesthetic to allow a comfortable experience for the patient.

The procedure starts with the placement of a longitudinal incision in the upper scrotum. The testis is delivered through the incision and the testis and epididymis are thoroughly inspected. Often, the site of epididymal obstruction can be grossly visible as an area where the epididymis transitions from a firm, wide caliber to a smaller, softer structure. The distal end of the vas deferens is mobilized in a similar fashion as that described above for the vasovasostomy but often a longer length is required to perform an epididymal anastomosis. At this point, the microscope is brought into the procedure to perform the anastomosis. Currently, three variations of the technique are popular for precise approximation of the lumen of the vas deferens to a single epididymal tubule: end-to-end, end-to-side, and end-to-side intussusception techniques. Each of these methods is described below. Prior to performing any of these techniques, an epididymal tubule must be identified which is immediately above the level of obstruction. To do this, a 1 cm incision is made in the epididymal tunic using curved microscissors (Figure 89.5A). This window allows exposure of multiple epididymal tubules. A single loop is identified and carefully dissected from surrounding

tubules. This tubule must be opened with precision and the fluid inspected for sperm. The method of opening the tubule is determined by the choice of anastomotic technique, as described below.

Fluid is examined from the opened epididymal tubule. If sperm are present, the anastomosis can be performed to the tubule at this level. If sperm are to be cryopreserved at the time of surgery, they can be aspirated as they flow from the opened loop, placed in an appropriate medium, and sent to the laboratory for cryopreservation. If no sperm are identified, a more proximal site of the epididymis will be required for the anastomosis.

End-to-end vasoepididymostomy

This technique, first described by Silber,¹⁰ involves dissection of a single epididymal tubule which is completely transected and then anastomosed to the vas lumen. In this technique, the end of the epididymis is serially transected until reaching a point just above the obstruction (Figure 89.4A). The cut end of the distal vas is brought into opposition with the portion of the cut tubule exuding sperm. Two 9-0 nylon sutures are placed at the 5 and 7 o'clock positions of the seromuscular surface of the vas, to secure the cut end of the distal vas to the epididymal tunica (Figure 89.4B). Next, four double armed 10-0 nylon sutures are placed in a quadrant fashion between the mucosa of the vas and the epididymal tubule (Figure 89.4C). These sutures are not tied until all have been positioned. Finally, the seromuscular layer of the vas to epididymal tunic layer is completed with several interrupted 9-0 nylon sutures (Figure 89.4D).

End-to-side vasoepididymostomy

In this method, widely popularized by Thomas,¹¹ the vas is mobilized and prepared in a similar fashion to the end-to-end technique. However, instead of transecting a single epididymal tubule, a microknife is used to make a 0.5–1 mm incision in the side of a single epididymal tubule. The vas is secured as described above with two 9-0 nylon sutures from the seromuscular vas surface to the epididymal tunic (Figure 89.5A). With the tubule opened and sperm presence confirmed, three or four double armed 10-0 nylon sutures are placed in a quadrant fashion through the edge of the epididymal tubule (Figure 89.5B). The sutures are placed in the corresponding quadrant of the vasal mucosa and tied. The anastomosis is completed with additional 9-0 nylon sutures between

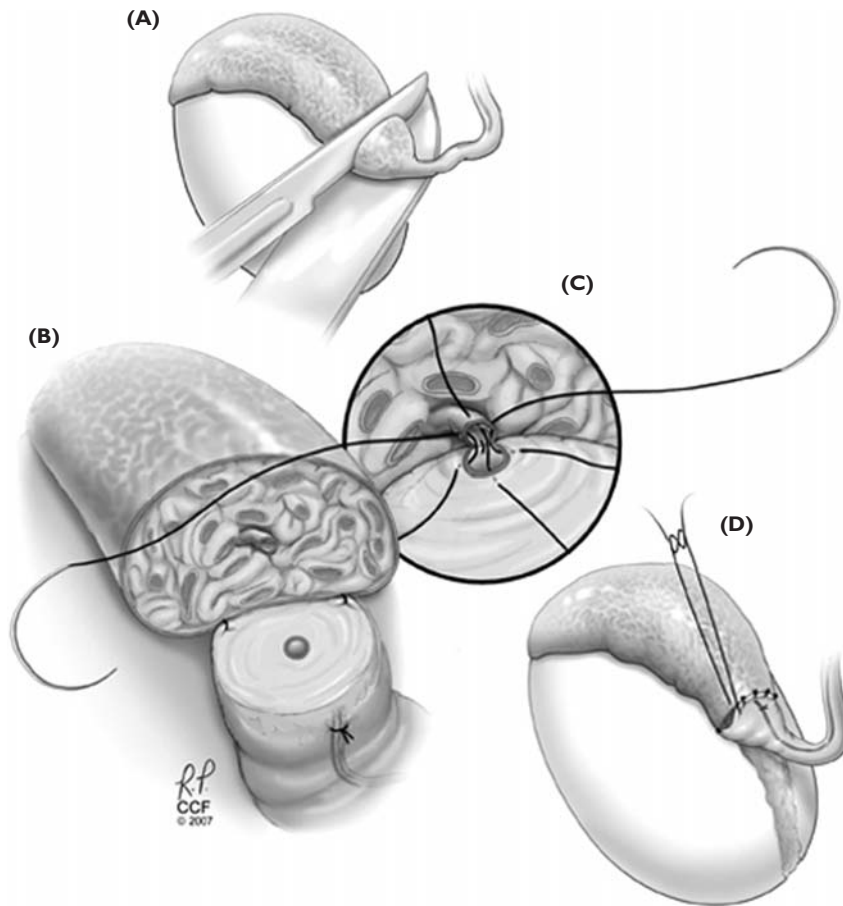


Figure 89.4 End-to-end vasoepididymostomy. (A) Epididymis is serially transected starting distally until a sperm-laden tubule is identified. (B) Two 9-0 nylon sutures are placed in the 5 and 7 o'clock positions to approximate the seromuscular wall of the end of the vas with the cut edge of the epididymal tunic. (C) Four 10-0 nylon double-armed sutures are placed in quadrant fashion between the epididymal and vasal mucosa. (D) Anastomosis is completed with additional 9-0 nylon sutures between the epididymal tunic and the seromuscular wall of the vas deferens. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

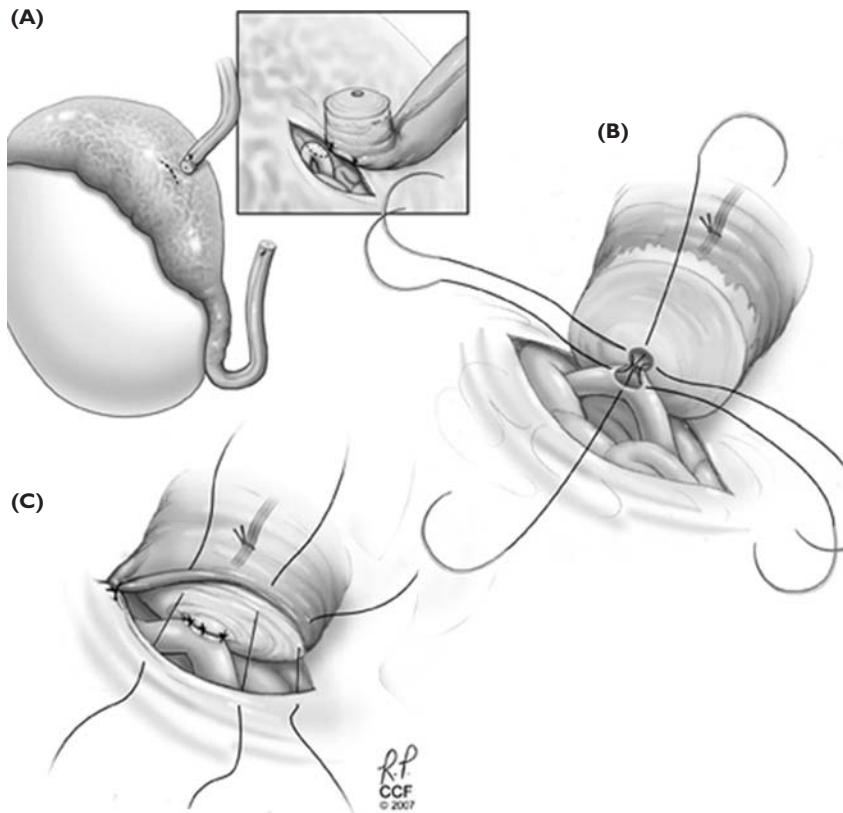


Figure 89.5 End-to-side vasoepididymostomy. (A) Epididymal tunic is incised exposing a loop of epididymal tubule. Inset shows epididymal tubule opened along dotted line in figure. Seromuscular wall of the vas deferens is secured to the cut edge of the epididymal tunic with two 9-0 nylon sutures placed in the 5 and 7 o'clock positions. (B) Quadrant double-armed 10-0 nylon sutures are placed in an into-out fashion in the epididymal and vasal mucosa. (C) After the inner 10-0 sutures are tied, 9-0 nylon interrupted sutures are used to approximate the epididymal tunic to the seromuscular layer of the vas. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

the epididymal tunic and the seromuscular layer of the vas deferens (Figure 89.5C). Finally, several 9-0 nylon sutures are used to anchor the vas deferens to the parietal layer of the tunica vaginalis. These final sutures are designed to prevent tension on the anastomosis and are placed well away from the vasoepididymostomy site.

End-to-side intussusception vasoepididymostomy

This technique was introduced by Berger¹⁵ with subsequent modifications by other authors.^{10,11} The intent is to allow the precision of the standard end-to-side anastomosis while simplifying and minimizing the microsuture placement. Rather than a direct approximation of the epididymal tubule to the vas, this method involves pulling the epididymal tubule into the vas lumen. As with the previous techniques, two 9-0 sutures are used to secure the muscular layer of the vas to the epididymal tunic. Unlike the previously described techniques, the epididymal tubule is opened after the sutures have been placed in the epididymal loop. Three double-armed 10-0 nylon sutures are placed in a triangular configuration in the desired epididymal tubule (Figure 89.6A). Next, the epididymal tubule is carefully opened with microscissors between the positioned sutures. Once the presence of sperm is confirmed in the epididymal fluid, the needles are passed through the lumen of the vas in an inside-out fashion. The sutures are then tied, creating an invagination of the epididymal tubule into the vasal lumen (Figure 89.6B and C). Finally, additional 9-0 nylon sutures are placed to approximate the seromuscular layer of the vas to the epididymal tunic.

Vasoepididymostomy results

Results tend to vary significantly based on the experience level of the surgeon, surgical technique used, the level of the epididymal obstruction, and the reproductive capacity of the partner. Table 89.2 summarizes the contemporary patency and pregnancy rates for vasoepididymal anastomosis.

CONCLUSION

Advances in microsurgical technique, microscopes, and surgical equipment have allowed the restoration

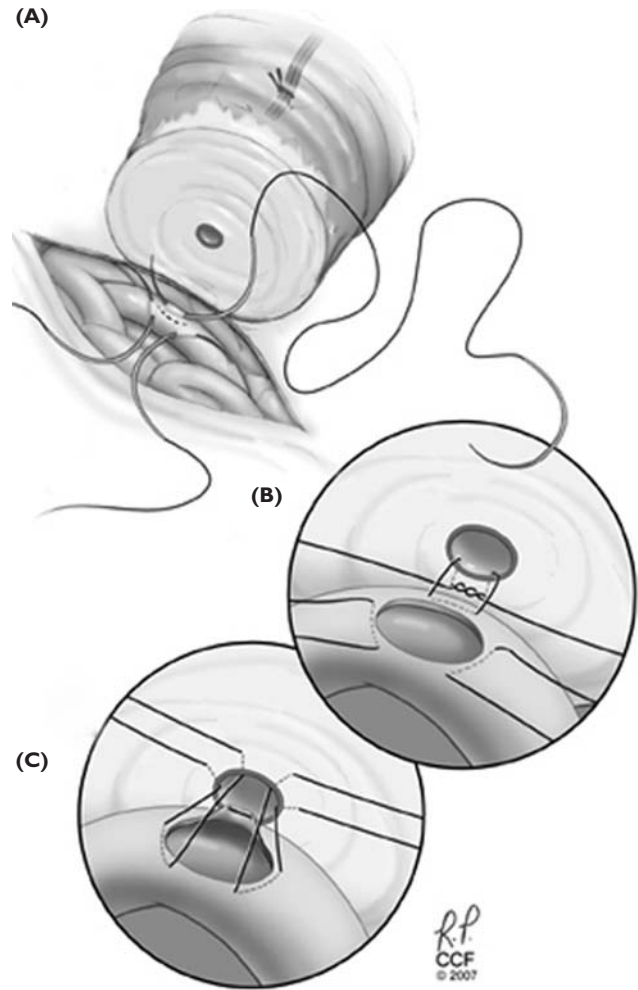


Figure 89.6 Intussusception end-to-side vasoepididymostomy. (A) Three double-armed 10-0 nylon sutures are placed in a triangulated fashion in the epididymal loop. The needles are left in place until all have been placed to avoid decompressing the tubule which could make suture placement more difficult. Tubule is incised along the dotted line after suture placement. (B) Ends of the sutures are placed in-to-out in the vasal mucosa. (C) Sutures are tied to allow intussusception of the epididymal tubule into the vas lumen. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

of genital tract patency after vasal interruption. Outcomes ultimately are dependent on the surgeon's experience with their chosen technique. Regardless of the surgical anastomosis method used, it is critical that the surgeon who undertakes vasectomy reversal be prepared for and skilled with vasoepididymostomy techniques since there is a significant likelihood that an epididymal anastomosis will be required.

Table 89.2 Vasoepididymostomy outcomes

Author	Year	Number of patients	Anastomosis	Patency (%)	Pregnancy (%)
Dubin and Amelar ¹²	1984	46	End-to-end	39	13
Silber ¹³	1989	139	End-to-end	78	56
Dewire and Thomas ¹⁴	1995	137	End-to-side	79	50
Berger ¹⁵	1998	12	Intussusception	92	Not reported
Marmar ¹⁶	2000	9	Intussusception	78	22
Chan and Li ¹⁷	2005	68	Intussusception	84	40
Schiff et al ^{18*}	2005	153	End-to-end	73	20
			End-to-side	74	40
			3-Suture intussusception	84	46
			2-Suture intussusception	80	44

* $p < 0.05$ comparing patency rates for surgical approaches between intussusception techniques and end-to-end or end-to-side vasoepididymostomies. No statistically significant differences in pregnancy rates between techniques.

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90 Tissue engineering: regenerative medicine

Anthony Atala

INTRODUCTION

Even in antiquity, the use of one body part for another or the exchange of parts from one person to another was mentioned in literature. For example in Genesis 2:21, it says, 'So the Lord God caused the man to fall into a deep sleep, and while he was asleep, He took part of the man's rib, and closed up the place with flesh. Then the Lord God made a woman from the part He had taken out of the man, and He brought her to the man.' In this text, four medical events are described: anesthesia, surgery, cloning, and tissue engineering. The performance of two of these, tissue engineering and cloning, were not possible even three decades ago. As medical research has progressed, we have seen all four achieved during our lifetime.

From the time of early development of a fetus, the genitourinary system is exposed to a variety of possible injuries. Individuals may suffer from congenital disorders, cancer, trauma, infection, inflammation, iatrogenic injuries, or other conditions that may lead to genitourinary organ damage or loss and require eventual reconstruction. Whenever there is a lack of native urologic tissue, reconstruction may be performed with native non-urologic tissues (skin, gastrointestinal segments, or mucosa from multiple body sites), homologous tissues (cadaver fascia, cadaver, or donor kidney), heterologous tissues (bovine collagen), or artificial materials (silicone, polyurethane, Teflon² (DuPont, Johnston, IA)). The tissues used for reconstruction may lead to complications because of their inherently different functional parameters. In most cases, the replacement of lost or deficient tissues with functionally equivalent tissues would improve the outcome for these patients. This goal may be attainable with the use of tissue-engineering techniques.

TISSUE ENGINEERING: STRATEGIES FOR TISSUE RECONSTITUTION

Tissue engineering follows the principles of cell transplantation, materials science, and engineering toward the development of biologic substitutes that can restore and maintain normal function. Tissue engineering may involve matrices alone, wherein the body's natural ability to regenerate is used to orient or direct new tissue

growth, or it may use matrices with cells. One of the initial limitations of applying cell-based tissue-engineering techniques to urologic organs was the difficulty of growing genitourinary associated cells in large quantities. It seemed that normal urothelial cells had a natural senescence that was hard to overcome. The cells could be grown in the laboratory but with limited expansion. This was an early challenge that had to be overcome by those who would attempt regenerative medicine for urologic structures. Over the past two decades, several protocols have been developed to improve urothelial growth and expansion. When cells are used for tissue engineering, donor tissue is dissociated into individual cells, which are implanted directly into the host or expanded in culture, attached to a support matrix, and reimplanted after expansion. The implanted tissue can be heterologous, allogeneic, or autologous. Ideally, this approach allows lost tissue function to be restored or replaced in toto and with limited complications.¹⁻¹⁸

BIOMATERIALS FOR GENITOURINARY TISSUE ENGINEERING

Biomaterials in genitourinary tissue engineering function as an artificial extracellular matrix (ECM) and elicit biologic and mechanical functions of native ECM found in tissues in the body. Biomaterials facilitate the localization and delivery of cells and/or bioactive factors (e.g. cell adhesion peptides, growth factors) to desired sites in the body; define a three-dimensional space for the formation of new tissues with appropriate structure; and guide the development of new tissues with appropriate function.¹⁹ The mechanical support of the biomaterials should be maintained until the engineered tissue has sufficient mechanical integrity to support itself.⁹ Direct injection of cell suspensions without biomaterial matrices has been used in some cases,^{20,21} but it is difficult to control the localization of transplanted cells.

Types of biomaterials

The ideal biomaterial should be biocompatible, promote cellular interaction and tissue development, and

possess proper mechanical and physical properties. Generally, three classes of biomaterials have been used for engineering of genitourinary tissues: naturally derived materials, such as collagen and alginate; acellular tissue matrices, such as bladder submucosa and small intestinal submucosa (SIS); and synthetic polymers, such as polyglycolic acid (PGA), polylactic acid (PLA), and poly(lactic-co-glycolic acid) (PLGA). Naturally derived materials and acellular tissue matrices have the potential advantage of biologic recognition. Collagen is the most abundant and ubiquitous structural protein in the body and can be readily purified from animal and human tissues. Alginate, a polysaccharide isolated from seaweed, has gentle gelling properties in the presence of divalent cations and can be useful because it is relatively biocompatible, but the cross-linking that causes the gelling can be lost. Synthetic polymers can be produced reproducibly on a large scale with controlled properties of strength, degradation rate, and microstructure.¹⁹

VASCULARIZATION

One of the restrictions of the engineering of tissues is that cells cannot be implanted in volumes exceeding 3 mm³ because of the limitations of nutrition and gas exchange.²² To achieve the goals of engineering large complex tissues, and possibly internal organs, vascularization of the regenerating cells is essential.

Three approaches have been used for vascularization of bioengineered tissue: incorporation of angiogenic factors in the bioengineered tissue, seeding ECM with other cell types in the bioengineered tissue, and prevascularization of the matrix prior to cell seeding. Angiogenic growth factors may be incorporated into the bioengineered tissue prior to implantation, in order to attract host capillaries and to enhance neovascularization of the implanted tissue. There are many obstacles to overcome before large entire tissue-engineered solid organs are produced. Recent developments in angiogenesis research may provide important knowledge and essential materials to accomplish this goal.

TISSUE ENGINEERING OF UROLOGIC STRUCTURES

Urethra

Various strategies have been proposed over the years for the regeneration of urethral tissue. Woven meshes of PGA (Dexon™ United States Surgical, Norfolk, CT), without cells, have been used to reconstruct urethras

in dogs.^{23,24} PGA has been used as a cell transplantation vehicle to engineer tubular urothelium *in vivo*.¹ SIS without cells has been used as an onlay patch graft for urethroplasty in rabbits.²⁵ A homologous free graft of acellular urethral matrix has also been used in a rabbit model.²⁶

Bladder-derived acellular collagen matrix has proven to be a suitable graft for repair of urethral defects in rabbits. In the rabbit model the neourethras created demonstrated a normal urothelial luminal lining and organized muscle bundles.²⁷ These results were confirmed clinically in a series of patients with a history of failed hypospadias reconstruction wherein the urethral defects were repaired with human bladder acellular collagen matrices (Figure 90.1).²⁸ One of its advantages over non-genital tissue grafts used for urethroplasty is that the material is 'off the shelf'. This eliminates the necessity of additional surgical procedures for graft harvesting, which may decrease operative time, as well as reducing the potential morbidity due to the harvest procedure.

The above techniques, using non-seeded acellular matrices, were applied experimentally and clinically in a successful manner for onlay urethral repairs. However, when tubularized urethral repairs were attempted experimentally, adequate urethral tissue regeneration was not achieved, and complications ensued, such as graft contracture and stricture formation.²⁹ Seeded tubularized collagen matrices have performed better in animal studies. In a rabbit model, entire urethral segments were resected and urethroplasties were performed with tubularized collagen matrices either seeded with cells, or without cells. The tubularized collagen matrices seeded with autologous cells formed new tissue which was histologically similar to native urethra. The tubularized collagen matrices without cells lead to poor tissue development, fibrosis, and stricture formation. These findings were recently confirmed clinically.³⁰

Bladder

Currently, gastrointestinal segments are commonly used as tissues for bladder replacement or repair. However, gastrointestinal tissues are designed to absorb specific solutes, and when they come in contact with the urinary tract multiple complications may ensue, such as infection, metabolic disturbances, urolithiasis, perforation, increased mucus production, and malignancy.^{31,32} Because of the problems encountered with the use of gastrointestinal segments, numerous investigators have attempted alternative

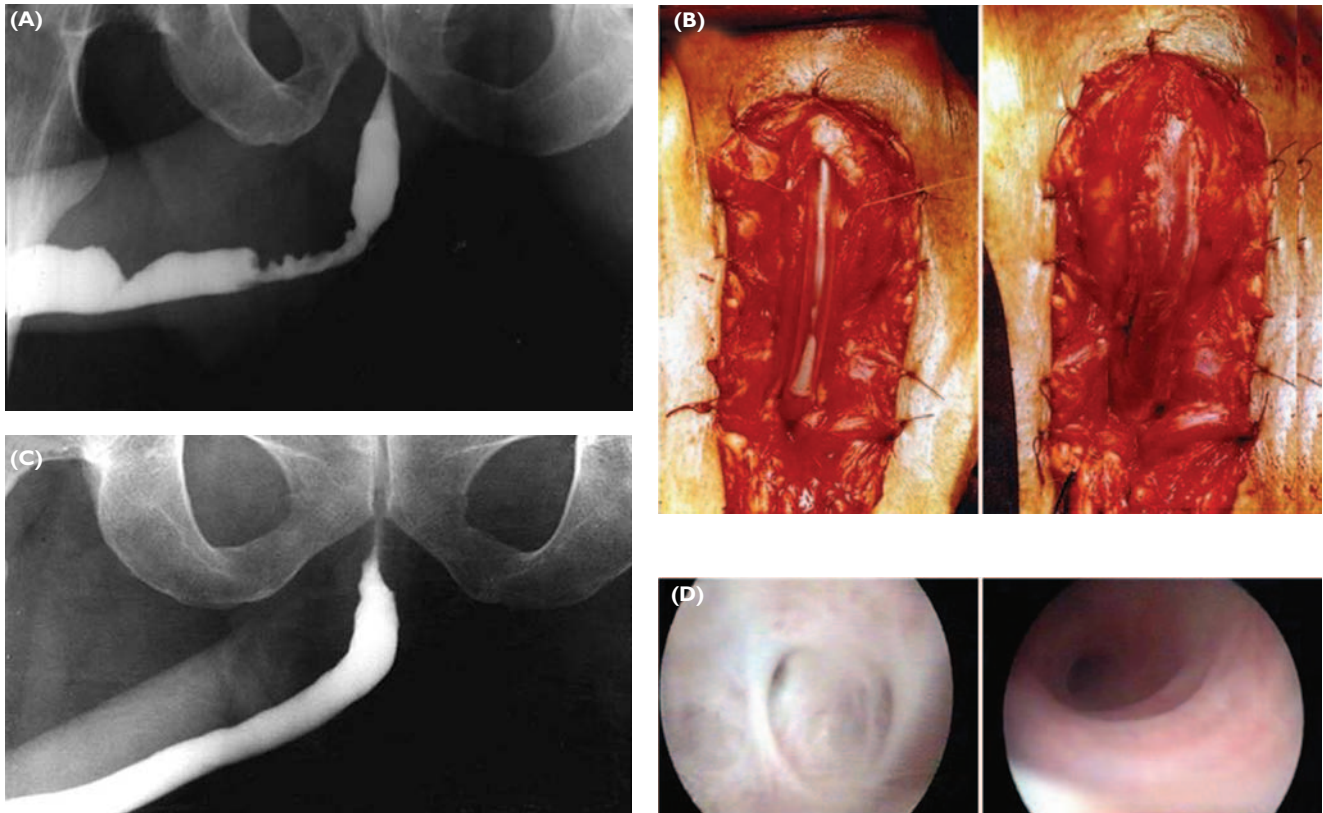


Figure 90.1 Tissue engineering of the urethra using a collagen matrix. (A) Representative case of a patient with a bulbar stricture. (B) Urethral repair. Strictured tissue is excised, preserving the urethral plate on the left side, and matrix is anastomosed to the urethral plate in an onlay fashion on the right. (C) Urethrogram 6 months after repair. (D) Cystoscopic view of urethra before surgery on the left side and 4 months after repair on the right side.

reconstructive procedures for bladder replacement or repair such as the use of tissue expansion, seromuscular grafts, matrices for tissue regeneration, and tissue engineering with cell transplantation.

A clinical trial involving engineered bladder tissue for cystoplasty reconstruction was conducted starting in 1999. A small pilot series of seven patients was reported, using a collagen scaffold seeded with cells either with or without omentum coverage, or a combined PGA-collagen scaffold seeded with cells and omental coverage (Figure 90.2). The patients reconstructed with the engineered bladder tissue created with the PGA-collagen cell-seeded scaffolds showed increased compliance, decreased end-filling pressures, increased capacities, and longer dry periods.³³

Tissue expansion for bladder augmentation

A system of progressive dilatation for ureters and bladder has been proposed as a method of bladder augmentation but has not yet been attempted clinically.^{34,35} Augmentation cystoplasty performed with the dilated ureteral segment in animals has resulted in an increased

bladder capacity ranging from 190 to 380%.³⁴ A system for the progressive expansion of native bladder tissue has also been used for augmenting bladder volumes in animals. Within 30 days after progressive dilatation, the neoreservoir volume was expanded at least tenfold. Urodynamic studies showed normal compliance in all animals, and microscopic examination of the expanded neoreservoir tissue showed a normal histology. A series of immunocytochemical studies demonstrated that the dilated bladder tissue maintained normal phenotypic characteristics.³⁵ Ideally, bladder tissue expansion could be performed with an indwelling dilatation catheter, similar to a Foley catheter, with a large balloon. An expanding balloon within the catheter could then be filled progressively, either continuously or intermittently, until the desired bladder volume is achieved.

Seromuscular grafts and de-epithelialized bowel segments

Seromuscular grafts and de-epithelialized bowel segments, either alone or over a native urothelium, have also been attempted.^{36–42} Keeping the urothelium

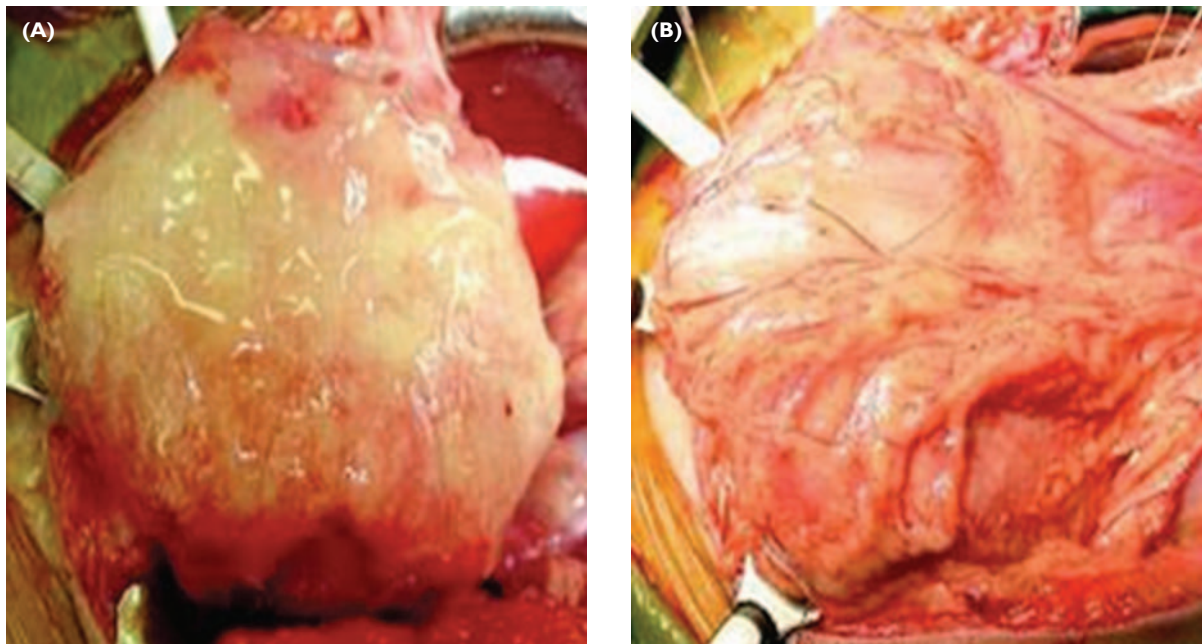


Figure 90.2 Construction of engineered bladder. (A) Engineered bladder anastomosed to native bladder with running 4-0 polyglycolic sutures. (B) Implant covered with fibrin glue and omentum.

intact avoids the complications associated with use of bowel in continuity with the urinary tract.^{37,38} An example of this strategy is the combination of the techniques of autoaugmentation with those of enterocystoplasty. An autoaugmentation is performed, and the diverticulum is covered with a demucosalized gastric or intestinal segment.⁴² These investigative efforts have emphasized the complexity of both the anatomic and cellular interactions present when tissues with different functional parameters are combined.

Matrices for bladder regeneration

Non-seeded allogeneic acellular bladder matrices have served as scaffolds for the ingrowth of host bladder wall components. The matrices are prepared by mechanically and chemically removing all cellular components from bladder tissue.^{14,43–45} The matrices serve as vehicles for partial bladder regeneration, and relevant antigenicity is not evident. For example, SIS, a biodegradable, acellular, xenogeneic collagen-based tissue-matrix graft, was first used in the early 1980s as an acellular matrix for tissue replacement in the vascular field. It has been shown to promote regeneration of a variety of host tissues, including blood vessels and ligaments.⁴⁶ Animal studies have shown that the non-seeded SIS matrix used for bladder augmentation is able to regenerate *in vivo*.^{47,48}

In multiple studies using various materials as non-seeded grafts for cystoplasty, the urothelial layer was able to regenerate normally, but the muscle layer,

although present, was not fully developed.^{14,43,44,48} Often the grafts contracted to 60–70% of their original sizes⁴⁹ with little increase in bladder capacity or compliance.⁵⁰ Studies involving acellular matrices that may provide the necessary environment to promote cell migration, growth, and differentiation are being conducted. With continued bladder research in this area, these matrices may have a clinical role in bladder replacement in the future. Recently, bladder regeneration has been shown to be more reliable when the SIS was derived from the distal ileum.⁴⁷

Bladder replacement using tissue engineering

Cell-seeded allogeneic acellular bladder matrices have been used for bladder augmentation in dogs. A group of experimental dogs underwent a trigone-sparing cystectomy and were randomly assigned to one of three groups. One group underwent closure of the trigone without a reconstructive procedure, another underwent reconstruction with a non-seeded bladder-shaped biodegradable scaffold, and the final group underwent reconstruction using a bladder-shaped biodegradable scaffold that delivered seeded autologous urothelial cells and smooth muscle cells.¹⁷

The cystectomy-only and non-seeded controls maintained average capacities of 22% and 46% of preoperative values, respectively. An average bladder capacity of 95% of the original precystectomy volume was achieved in the cell-seeded tissue-engineered bladder replacements (Figure 90.3). The subtotal cystectomy reservoirs

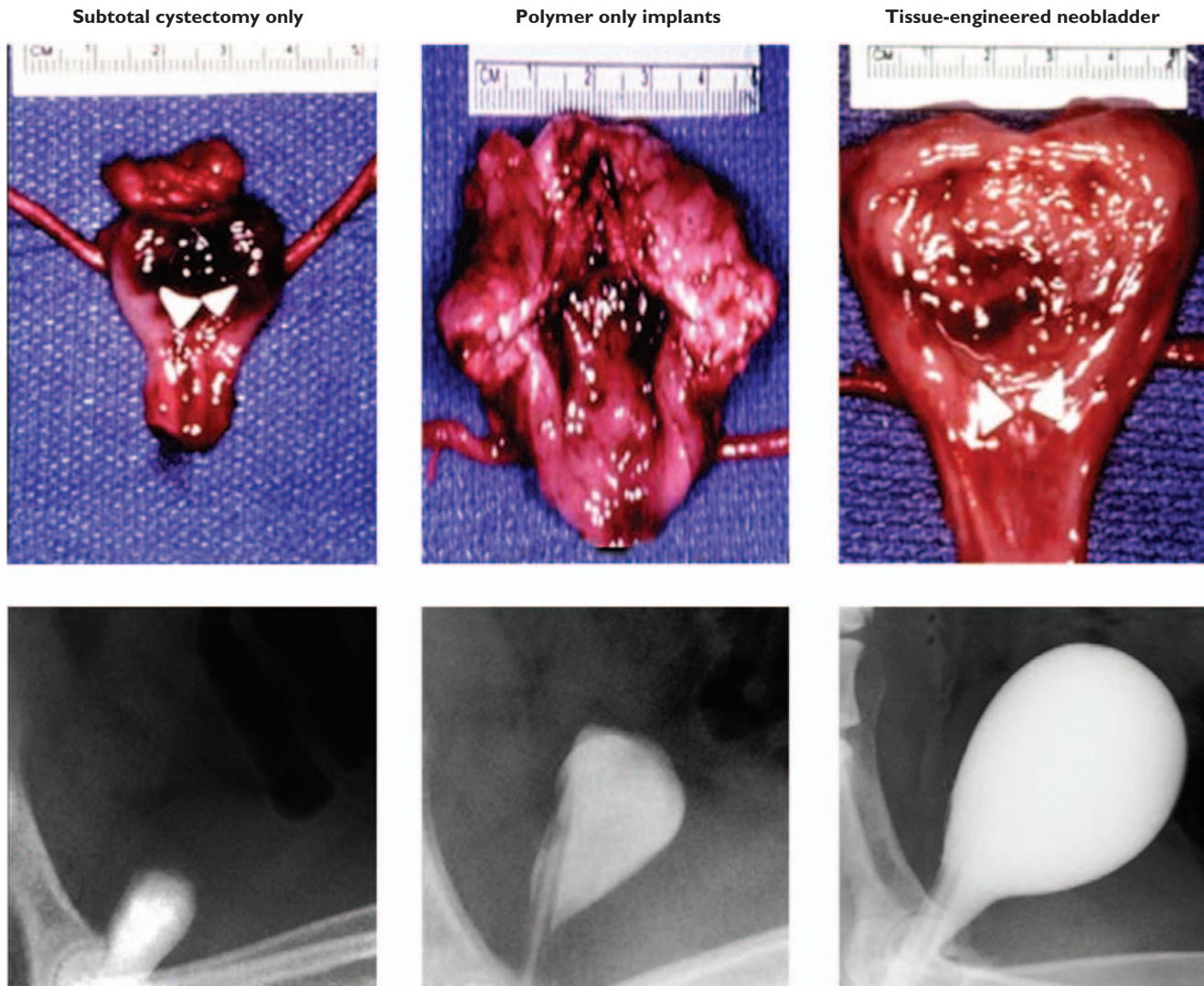


Figure 90.3 Gross specimens and cystograms at 11 months of the cystectomy-only and non-seeded controls, and cell-seeded tissue-engineered bladder replacements. The cystectomy-only bladder had a capacity of 22% of the preoperative value and a decrease in bladder compliance to 10% of the preoperative value. The non-seeded controls showed significant scarring with a capacity of 46% of the preoperative value and a decrease in bladder compliance to 42% of the preoperative value. An average bladder capacity of 95% of the original precystectomy volume was achieved in the cell-seeded tissue-engineered bladder replacements and the compliance showed almost no difference from preoperative values that were measured when the native bladder was present (106%).

that were not reconstructed and the polymer-only reconstructed bladders showed a marked decrease in bladder compliance (10% and 42% total compliance, respectively). The compliance of the cell-seeded tissue-engineered bladders showed almost no difference from preoperative values that were measured when the native bladder was present (106%). Histologically, the non-seeded scaffold bladders presented a pattern of normal urothelial cells with a thickened fibrotic submucosa and a thin layer of muscle fibers. The retrieved tissue-engineered bladders showed a normal cellular organization, consisting of a trilayer of urothelium, submucosa, and muscle.¹⁷ Preliminary clinical trials for the application of this technology have been performed,

and the results are promising, although more research is planned in this area.³³

Genital tissues

Reconstruction of corporeal smooth muscle

One of the major components of the phallus is corporeal smooth muscle. The creation of autologous functional and structural corporeal tissue de novo would be beneficial. In order to look at the functional parameters of the engineered corpora, acellular corporeal collagen matrices were obtained from donor rabbit penis and autologous corpus cavernosal smooth muscle, and endothelial cells

were harvested, expanded, and seeded on the matrices. The entire rabbit corpora was removed and replaced with the engineered scaffolds. The experimental corporeal bodies demonstrated intact structural integrity by cavernosography and showed similar pressure by cavernosometry when compared with the normal controls. The control rabbits without cells failed to show normal erectile function throughout the study period. Mating activity in the animals with the engineered corpora appeared normal by 1 month after implantation. The presence of sperm was confirmed during mating, and was present in all the rabbits with the engineered corpora. The female rabbits mated with the animals implanted with engineered corpora, and conceived and delivered healthy pups. Animals implanted with the matrix alone were unable to demonstrate normal mating activity and failed to ejaculate into the vagina.⁵¹

Engineered penile prostheses

Although silicone is an accepted biomaterial for penile prostheses, biocompatibility is a concern.^{52,53} The use of a natural prosthesis composed of autologous cells may be advantageous. In a recent study using an autologous system, the feasibility of applying engineered cartilage rods in situ was investigated.⁵⁴ Autologous chondrocytes harvested from rabbit ear were grown and expanded in culture. The cells were seeded onto biodegradable poly-L-lactic acid coated polyglycolic acid polymer rods and implanted into the corporeal spaces of rabbits. Examination at retrieval showed the presence of well formed, milky-white cartilage structures within the corpora at 1 month. All polymers were fully degraded by 2 months. There was no evidence of erosion or infection in any of the implantation sites. Subsequent studies were performed to assess the long-term functionality of the cartilage penile rods in vivo. To date, the animals have done well and can copulate and impregnate their female partners without problems.

Female genital tissues

Congenital malformations of the uterus may have profound implications clinically. Patients with cloacal exstrophy and intersex disorders may not have sufficient uterine tissue present for future reproduction. We investigated the possibility of engineering functional uterine tissue using autologous cells.⁵⁵ Autologous rabbit uterine smooth muscle and epithelial cells were harvested, then grown and expanded in culture. These cells were seeded onto pre-configured uterine-shaped biodegradable polymer scaffolds, which were then used for subtotal uterine

tissue replacement in the corresponding autologous animals. Upon retrieval 6 months after implantation, histologic, immunocytochemical, and Western blot analyses confirmed the presence of normal uterine tissue components. Biomechanical analyses and organ bath studies showed that the functional characteristics of these tissues were similar to those of normal uterine tissue. Breeding studies using these engineered uteri are currently being performed.

Similarly, several pathologic conditions, including congenital malformations and malignancy, can adversely affect normal vaginal development or anatomy. Vaginal reconstruction has traditionally been challenging due to the paucity of available native tissue. Vaginal epithelial and smooth muscle cells of female rabbits were harvested, grown, and expanded in culture. These cells were seeded onto biodegradable polymer scaffolds, and the cell-seeded constructs were then implanted into nude mice for up to 6 weeks. Immunocytochemical, histologic, and Western blot analyses confirmed the presence of vaginal tissue phenotypes. Electrical field stimulation studies in the tissue-engineered constructs showed similar functional properties to those of normal vaginal tissue. When these constructs were used for autologous total vaginal replacement, patent vaginal structures were noted in the tissue-engineered specimens, while the non-cell-seeded structures were noted to be stenotic.⁵⁶

Ureters

Ureteral non-seeded matrices have been used as a scaffold for the ingrowth of ureteral tissue in rats. On implantation, the acellular matrices promoted the regeneration of the ureteral wall components.⁵⁷ Ureteral replacement with polytetrafluoroethylene (Teflon) grafts was also attempted in dogs, but with poor functional results.⁵⁸ In a more recent study, non-seeded ureteral collagen acellular matrices were tubularized and used to replace 3 cm segments of canine ureters. The non-seeded acellular matrix tube was not able to successfully replace the segment of the ureter.⁵⁹

Cell seeded biodegradable polymer scaffolds have been used with more success to reconstruct ureteral tissues. In one study, urothelial and smooth muscle cells isolated from bladders and expanded in vitro were seeded onto PGA scaffolds with tubular configurations and implanted subcutaneously into athymic mice. After implantation, the urothelial cells proliferated to form a multilayered luminal lining of tubular structures, while the smooth muscle cells organized into multilayered structures surrounding the urothelial

cells. Abundant angiogenesis was evident. The degradation of the polymer scaffolds resulted in the eventual formation of natural urothelial tissues. This approach was expanded to replacement of ureters in dogs by transplantation of smooth muscle cells and urothelial cells on tubular polymer scaffolds.⁶⁰

Kidney

The kidney is probably the most challenging organ in the genitourinary system to reconstruct by tissue-engineering techniques because of its complex structure and function. Emerging concepts for a bioartificial kidney are currently being explored. Some investigators are pursuing the replacement of isolated kidney function parameters with the use of extracorporeal units, while others are aiming at the replacement of total renal function by tissue-engineered bioartificial structures.

Ex vivo functioning renal units

Although dialysis is currently the most prevalent form of renal replacement therapy, the relatively high morbidity and mortality have spurred investigators to seek alternative solutions involving *ex vivo* systems. In an attempt to assess the viability and physiologic functionality of a cell-seeded device to replace the filtration, transport, metabolic, and endocrinologic functions of the kidney in acutely uremic dogs, a combination of a synthetic hemofiltration device and a renal tubular cell therapy device containing porcine renal tubules in an extracorporeal perfusion circuit was introduced. It was shown that levels of potassium and blood urea nitrogen (BUN) were controlled during treatment with the device. The fractional reabsorption of sodium and water was possible. Active transport of potassium, bicarbonate, and glucose, and a gradual ability to excrete ammonia was observed. These results showed the technologic feasibility of an extracorporeal assist device that is reinforced by the use of proximal tubular cells.⁶¹

Using similar techniques, the development of a tissue-engineered bioartificial kidney consisting of a conventional hemofiltration cartridge in series with a renal tubule assist device containing human renal proximal tubule cells was used in patients with acute renal failure in the intensive care unit. The initial clinical experience with the bioartificial kidney and the renal tubule assist device suggests that renal tubule cell therapy may provide a dynamic and individualized treatment program as assessed by acute physiologic and biochemical indices.⁶²

Creation of functional renal structures in vivo

Another approach towards the achievement of improved renal function involves the augmentation renal tissue with kidney cell expansion *in vitro* and subsequent autologous transplantation. The feasibility of achieving renal cell growth, expansion, and *in vivo* reconstitution with the use of tissue engineering techniques has been explored.

Most recently, an attempt was made to harness the reconstitution of renal epithelial cells for the generation of functional nephron units. Renal cells were harvested and expanded in culture. The cells were seeded onto a tubular device constructed from a polycarbonate membrane, connected at one end with a Silastic catheter that terminated into a reservoir. The device was implanted in athymic mice. Histologic examination of the implanted devices over time revealed extensive vascularization with formation of glomeruli and highly organized tubule-like structures. Immunocytochemical staining confirmed the renal phenotype. Yellow fluid was collected from inside the implant, and the fluid retrieved was consistent with the make-up of dilute urine in its creatinine and uric acid concentrations.⁶³ Further studies have been performed showing the formation of renal structures in cows using nuclear transfer techniques (Figure 90.4).⁶⁴ Challenges await this technology, including the expansion of this system to larger, three-dimensional structures.

OTHER APPLICATIONS OF GENITOURINARY TISSUE ENGINEERING

Fetal tissue engineering

The prenatal diagnosis of fetal abnormalities is now more prevalent and accurate. The natural consequence of the evolution in prenatal diagnosis is the use of intervention before birth to reverse potentially life-threatening processes.

There are several strategies that may be pursued to facilitate the future prenatal management of patients with urologic disease. Having a ready supply of urologic-associated tissue for surgical reconstruction at birth may be advantageous. Theoretically, once the diagnosis of the pathologic condition is confirmed prenatally, a small tissue biopsy could be obtained under ultrasound guidance. These biopsy materials could then be processed and the various cell types expanded *in vitro*. Using tissue-engineering techniques, reconstituted structures *in vitro* could then be readily available at the time of birth for reconstruction.

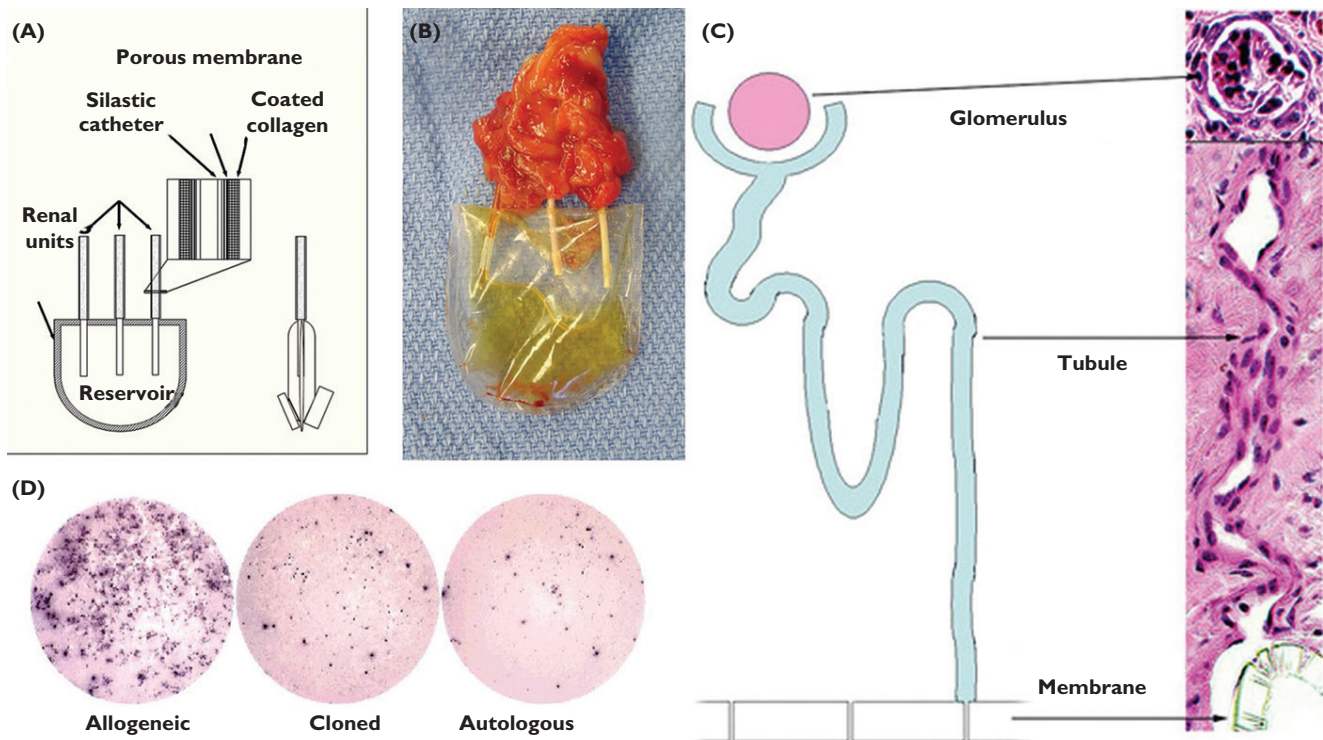


Figure 90.4 Combining therapeutic cloning and tissue engineering to produce kidney tissue. (A) Illustration of the tissue-engineered renal unit. (B) Renal unit seeded with cloned cells, 3 months after implantation, showing the accumulation of urine-like fluid. (C) There was a clear unidirectional continuity between the mature glomeruli, their tubules, and the polycarbonate membrane. (D) Elispot analyses of the frequencies of T cells that secrete interferon-gamma after primary and secondary stimulation with allogeneic renal cells, cloned renal cells, or nuclear donor fibroblasts.

Injectable therapies

Both urinary incontinence and vesicoureteral reflux are common conditions affecting the genitourinary system for which injectable bulking agents can be used for treatment. The ideal substance for endoscopic treatment of reflux and incontinence should be injectable, non-antigenic, non-migratory, volume stable, and safe for human use. Animal studies have shown that chondrocytes can be easily harvested and combined with alginate in vitro, the suspension can be easily injected cystoscopically, and the elastic cartilage tissue formed is able to correct vesicoureteral reflux without any evidence of obstruction.⁶⁵ The first human application of cell-based tissue-engineering technology for urologic applications occurred with the injection of chondrocytes for the correction of vesicoureteral reflux in children and for urinary incontinence in adults (Figure 90.5).^{66,67}

Using cell therapy techniques, the use of autologous smooth muscle cells was explored for both urinary incontinence and vesicoureteral reflux applications.⁶⁸ The potential use of injectable, cultured myoblasts for

the treatment of stress urinary incontinence has also been investigated.^{69,70} The use of injectable muscle precursor cells has also been investigated for use in the treatment of urinary incontinence due to irreversible urethral sphincter injury or maldevelopment.⁷¹ A clinical trial involving the use of muscle derived stem cells (MDSC) to treat stress urinary incontinence has also been performed with good results. Biopsies of skeletal muscle were obtained, and autologous myoblasts and fibroblasts were cultured. Under ultrasound guidance, myoblasts were injected into the rhabdosphincter, and fibroblasts mixed with collagen were injected into the submucosa. One year following injection, the thickness and function of the rhabdosphincter had significantly increased and all patients were continent.⁷² These are the first demonstrations of the replacement of both sphincter muscle tissue and its innervation by the injection of muscle precursor cells.

In addition, injectable muscle-based gene therapy and tissue engineering were combined to improve detrusor function in a bladder injury model, and may potentially be a novel treatment option for urinary incontinence.⁷³

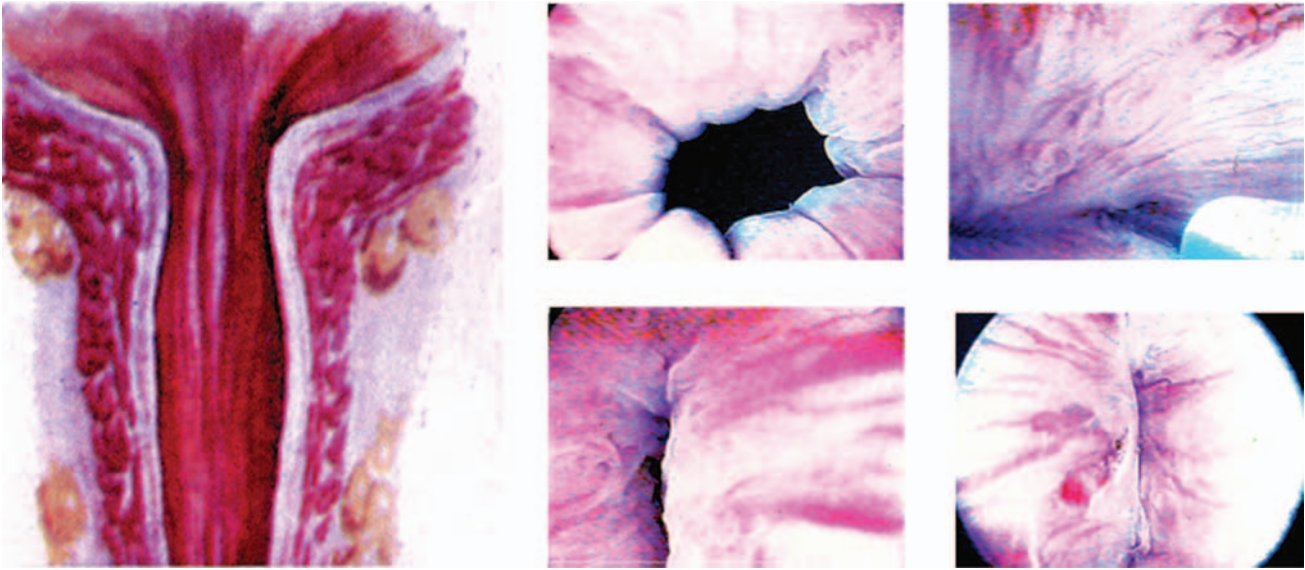


Figure 90.5 Chondrocytes are harvested and combined with alginate in vitro, and the suspension is injected cystoscopically as a bulking agent to treat urinary incontinence.

Testicular hormone replacement

Patients with testicular dysfunction require androgen replacement for somatic development. Conventional treatment for testicular dysfunction consists of periodic intramuscular injections of chemically modified testosterone or, more recently, skin patch applications. However, long-term non-pulsatile testosterone therapy is not optimal and can cause multiple problems, including erythropoiesis and bone density changes.

A system was designed wherein Leydig cells were microencapsulated for controlled testosterone replacement. Purified Leydig cells were isolated and encapsulated in an alginate-poly-L-lysine solution. The encapsulated Leydig cells were injected into castrated animals, and serum testosterone was measured serially; the animals were able to maintain testosterone levels in the long term.⁷⁴ These studies suggest that microencapsulated Leydig cells may be able to replace or supplement testosterone in situations where anorchia or testicular failure is present.

CONCERNS IN TISSUE ENGINEERING

An area of concern in the field of tissue engineering in the past was the source of cells for regeneration. The concept of creating engineered constructs involves initially obtaining cells for expansion from the diseased organ. A study recently showed that cultured neuro-pathic bladder smooth muscle cells possess and maintain

different characteristics to normal smooth muscle cells in vitro, as demonstrated by growth assays, contractility and adherence tests in vitro.⁷⁵ However, when neuro-pathic smooth muscle cells were cultured in vitro, and seeded onto matrices and implanted in vivo, the tissue-engineered constructs showed the same properties as the tissues engineered with normal cells.⁷⁶ It is known that genetically normal progenitor cells, which are the reservoirs for new cell formation, are programmed to give rise to normal tissue, regardless of whether the niche resides in either normal or diseased tissues. The stem cell niche and its role in normal tissue regeneration remains a fertile area of ongoing investigation.

Stem cells for tissue engineering

Most current strategies for tissue engineering depend upon a sample of autologous cells from the diseased organ of the host. However, for many patients with extensive end-stage organ failure, a tissue biopsy may not yield enough normal cells for expansion and transplantation. In other instances, primary autologous human cells cannot be expanded from a particular organ, such as the pancreas. In these situations, pluripotent human embryonic stem cells are envisioned as a viable source of cells, as they can serve as an alternative source of cells from which the desired tissue can be derived.

Embryonic stem cells exhibit two remarkable properties: the ability to proliferate in an undifferentiated,

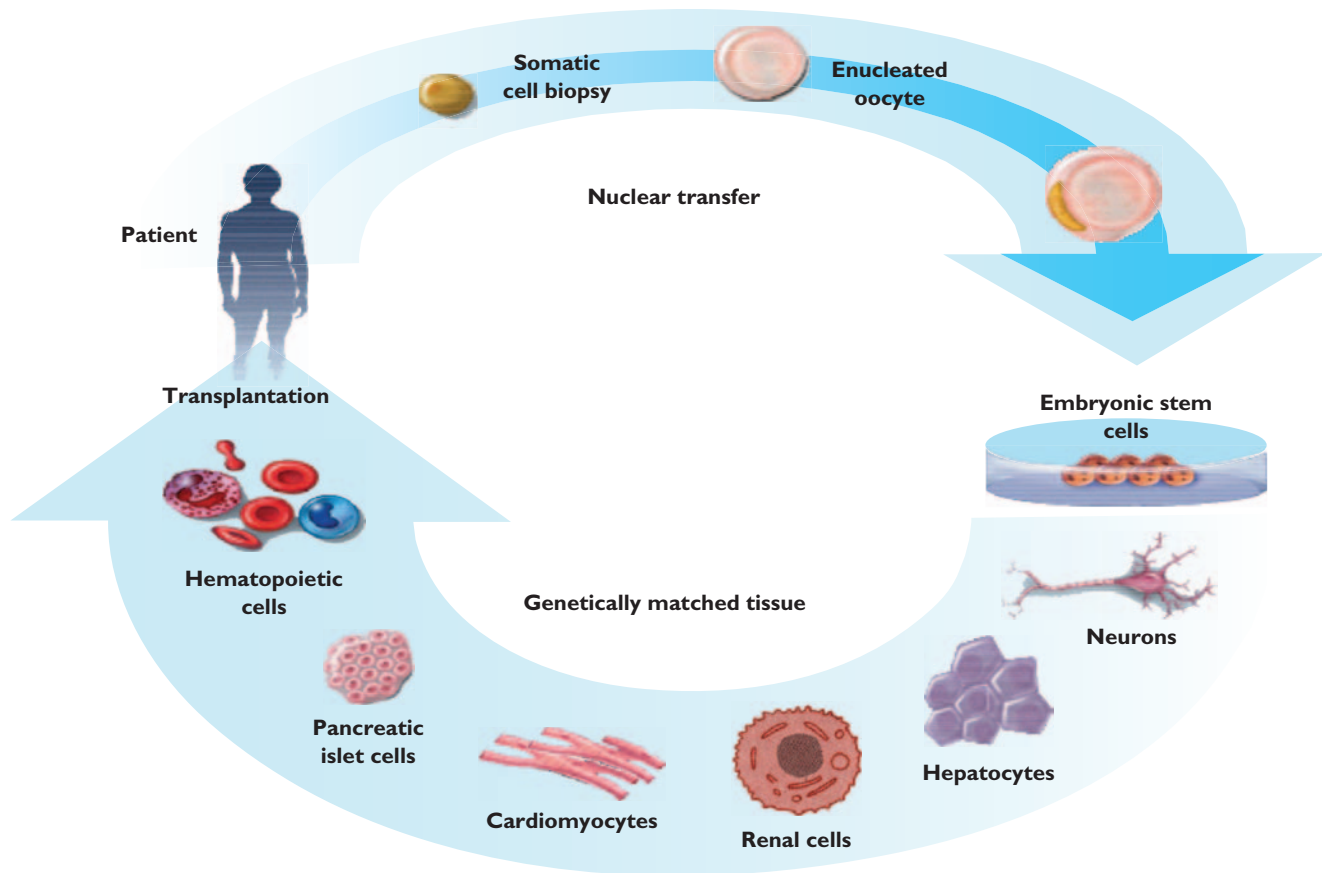


Figure 90.6 Strategy for therapeutic cloning and tissue engineering.

but pluripotent state (self-renew); and the ability to differentiate into many specialized cell types.⁷⁷ They can be isolated by immunosurgery from the inner cell mass of the embryo during the blastocyst stage (5 days postfertilization). These cells have demonstrated longevity in culture by maintaining their undifferentiated state for at least 80 passages when grown using current published protocols.⁷⁸

Adult stem cells have the advantage of avoiding some of the ethical issues associated with embryonic cells, and also they do not transdifferentiate spontaneously to a malignant phenotype. The use of adult stem cells is limited for clinical therapy due to the difficulties encountered with cell expansion to large quantities.

Fetal stem cells derived from amniotic fluid and placentas have been recently described and represent a novel source of stem cells. The cells express markers consistent with human embryonic stem cells, such as OCT4 and SSEA-4, but do not form teratomas, and do not spontaneously transdifferentiate to a malignant phenotype. The cells are multipotent and are able to differentiate into all three germ layers. In addition, the cells have a high replicative potential and could be

stored for future self-use, without the risks of rejection, and without ethical concerns.⁷⁹

Therapeutic cloning

Nuclear cloning, which has also been called nuclear transplantation and nuclear transfer, involves the introduction of a nucleus from a donor cell into an enucleated oocyte to generate an embryo with a genetic make-up identical to that of the donor. Two types of nuclear cloning, reproductive cloning and therapeutic cloning, have been described. Banned in most countries for human applications, reproductive cloning is used to generate an embryo that has the identical genetic material to its cell source. This embryo can then be implanted into the uterus of a female to give rise to an infant that is a clone of the donor. On the other hand, therapeutic cloning is used to generate early stage embryos that are explanted in culture to produce embryonic stem cell lines whose genetic material is identical to that of its source. These autologous stem cells have the potential to

become almost any type of cell in the adult body, and thus would be useful in tissue and organ replacement applications (Figure 90.6).⁸⁰ Some useful applications would be in the treatment of diseases, such as end-stage kidney disease, for which there is limited availability of immunocompatible tissue transplants.

CONCLUSION

Tissue-engineering efforts are currently being undertaken for every type of tissue and organ within the urinary system. Most of the effort expended to engineer genitourinary tissues has occurred within the past decade. Tissue-engineering techniques require a cell culture facility designed for human application. Personnel who have mastered the techniques of cell harvest, culture, and expansion as well as polymer design are essential for the successful application of this technology. Before these engineering techniques can be applied to humans, further studies need to be performed in many of the tissues described. Recent progress suggests that engineered urologic tissues and cell therapy may have clinical applicability.

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91 Gene therapy of the urogenital system

Arnold Melman and Kelvin Davies

If the genome is the blueprint of life, then genes and the proteins that they encode are the basic physical and functional units translated from this blueprint. Genes are specific sequences of bases that encode instructions on how to make proteins. When genes or their expression are altered so that the encoded proteins are unable to carry out their normal functions, pathophysiological disorders can arise. Gene therapy is a technique to correct the abnormal expression of genes responsible for disease development and represents the next potential era of advancement in medicine for the prevention of the effects of aging or for treatment of genetic or acquired disease. The concept of gene therapy is that the intermittent or single addition of a selective gene causes the body to manufacture natural proteins using a participant's own cells as minibioreactors. These naturally produced proteins can correct the abnormalities of cellular function and thereby can correct abnormal physiologic function.

Several approaches to restoring normal gene expressed products fall under the description of gene therapy. When an abnormal gene sequence is expressed through either an inherited germline mutation or spontaneous somatic

mutation, then a normal gene may be inserted into a non-specific location within the genome to replace a non-functional gene, the abnormal gene can be swapped for a normal gene through homologous recombination, or the gene may be repaired through selective reverse mutation, which returns the gene to its normal function.

In the case of the most commonly encountered urogenital diseases that are not inherited and develop later in a participant's life, it is the regulation of a particular gene (the degree to which a gene is turned on or off) that usually is altered. In these participants, gene therapy strategies are aimed at restoring normal levels of expression of the gene. For genes that are downregulated, the most commonly used approach has been to express the native gene from a heterologous promoter (DNA derived from a different species). If the gene is overexpressed abnormally, several potential mechanisms also may be used to knock down expression (e.g. gene silencing nucleic acids, such as ribozymes, DNA enzymes, antisense oligonucleotides, and small interfering RNA rely on hybridization to accessible sites within target mRNA for activity). These different strategies are illustrated in Figure 91.1.

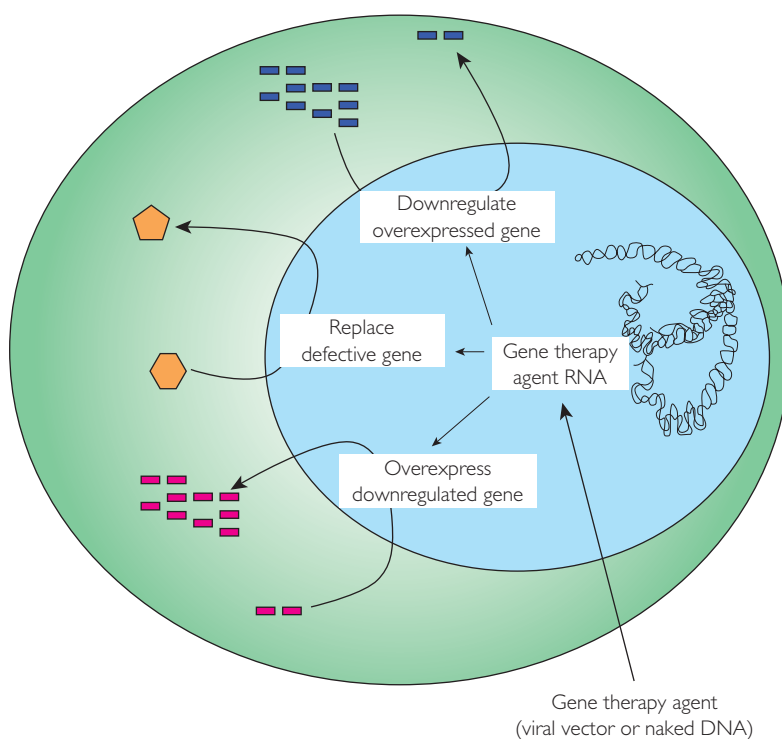


Figure 91.1 Illustration of different gene therapy strategies that are used to restore normal gene expression. If a gene is downregulated because of a pathologic condition, then a gene therapy vector can be designed that increases its expression. Or if a gene is overexpressed because of a pathologic condition, then gene therapy vectors can be used to downregulate its expression. If a gene is mutated, then a normal gene can be introduced into the affected cell.

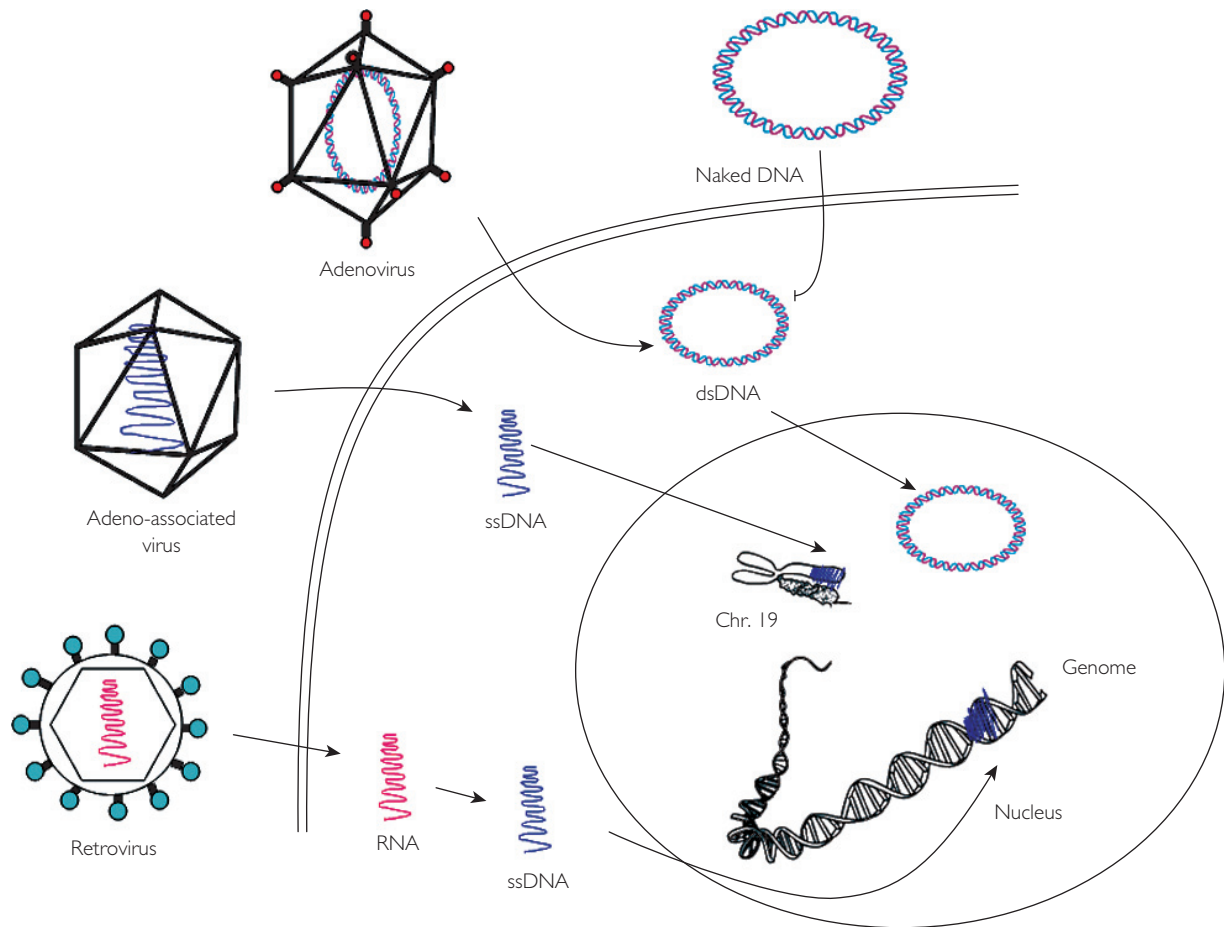


Figure 91.2 Illustration of the most commonly used vectors to transfer DNA into cells: retrovirus, adeno-associated virus, adenovirus, and naked DNA. Chr 19, chromosome 19; ssDNA, single strand DNA; dsDNA, double strand DNA.

VECTORS USED FOR GENE THERAPY

The development of safe and efficient vectors (viruses and plasmids) that allow delivery of a gene into the cells of interest, enabling the new gene to bypass the body's natural defense mechanisms, is the main challenge to gene therapy. Serious adverse events, including death caused by the host response to viral vectors used to gain entry of the recombinant DNA into the cells of interest, thus far have limited the widespread interest and progress in the field. In particular, for non-life-threatening applications in urologic diseases such as erectile dysfunction (ED) and overactive bladder, pharmaceutical industrial interest has been quiescent. Therefore, progress in the field has been left to the urologic laboratories in several medical centers with long-standing interest in ED. Until recently, any reports have been from studies at the preclinical, early stage that use a variety of vectors and genes.

The vectors used fall into two broad categories: viral and non-viral. The most commonly used viral vectors are retroviruses, adenovirus, herpes simplex virus, and adeno-associated viruses. Non-viral methods make use of naked DNA, as either a plasmid or polymerase chain reaction (PCR) product or synthetic oligonucleotides. The DNA used in the non-viral methods often is complexed into polymers to increase their uptake into cells. The different types of vectors are shown in Figure 91.2.

Retroviruses

Retroviral vectors were the first genetic vectors to permit an efficient and stable gene transfer into mammalian cells,^{1,2} and the first vectors used in a gene therapy clinical trial (for adenosine deaminase deficiency).² The genetic material in retroviruses is RNA,

but as soon as the virus enters the host cell, the RNA is converted to DNA by the process of reverse transcription. The DNA then enters the nucleus of the cell, where it integrates into the genome through the action of the viral enzyme integrase. Because the DNA is inserted in the genome, when the cell divides, the genetic information is transferred to the daughter cells. One of the major problems with the use of retroviruses is that potentially non-specific integration may inadvertently activate oncogenes. This oncogenetic potential was the cue of leukemias that resulted in the halting of gene therapy trials to treat severe combined immunodeficiency disease in the US.³

Adenoviruses

Adenoviruses, unlike the retroviral vectors, do not integrate into the host genome, and therefore are not likely to cause direct activation of oncogenes. Adenoviruses carry their genetic material as double-stranded DNA. When the virus enters the host cell, it does not integrate into the genome, but rather remains free in the nucleus, where the DNA is transcribed like any other gene. The virus does not replicate as the cell divides, so that as the cell propagates, the gene gradually is diluted. However, adenoviruses can cause a severe immune response. In 1999, a volunteer, Jesse Gelsinger, died within 48 hours of receiving intrahepatic administration of a recombinant adenoviral vector expressing ornithine transcarbamylase, which resulted in greater scrutiny and regulation of gene therapy clinical trials.⁴ In addition, a major histocompatibility complex (MHC) class I restricted immune response eliminates virus-infected cells, and the promoters of those cells that avoid the immune response are inactivated. Persisting antibodies limit the effectiveness of subsequent administration of the vector. The lack of integration into the genome should prevent development of cancers; however, the adenovirus needs to be readministered regularly when a cell population is growing.

Adeno-associated viruses

Adeno-associated viruses carry their genetic material as single-stranded DNA and insert the genetic material into a very specific site on chromosome 19. They are non-pathogenic and infect both dividing and non-dividing cells, such as neurons, and they are expressed for a long period. The viruses are somewhat immunogenic because of antibody to the adeno-associated virus capsid, and the virus may need to be readministered to maintain gene expression.

Herpes simplex virus

Herpes simplex virus type 1 (HSV-1) is a human neurotropic virus, and there has been interest in using HSV-1 as a vector for gene transfer to the nervous system.⁵ However, strong inflammatory responses to HSV-1 amplicon vectors can occur, at both the primary site of the injection and secondary sites supplied by nerve fibers originating from the area of the injection. In addition, up to 20% of experimental animals may die shortly after injection with HSV-1 vector, although the reason for this is unknown.⁶

Naked DNA

Naked DNA is the simplest non-viral transfection technique. Initially, it was believed that its low rate of uptake by cells and non-integration would give limited gene expression; however, it is emerging as one of the safest gene therapy vectors.⁴ The vector is either plasmid expressing the gene of interest or a PCR product. Naked DNA has low immunogenicity and low uptake by cells. Attempts have been made to increase the uptake by tissues using electroporation or protecting the DNA from damage by incorporating the DNA into lipoplexes and polyplexes. Overall, naked DNA gene transfer is considered to be among the safest vectors for gene therapy, which is an important consideration when treating quality-of-life diseases (such as ED and bladder dysfunction), because the risk-benefit analysis is an important consideration when progressing to participant studies. Most of these safety advantages stem from the limited uptake of the naked DNA and its short half-life in the body. The various advantages and disadvantages of the different gene therapy vectors are shown in Table 91.1.

THE UROGENITAL SYSTEM AS A TARGET FOR GENE THERAPY

In treating ED, the penis has particular characteristics that make it amenable for gene therapy. It is easily accessible, has an endothelial-lined sinusoidal structure to accept the gene for distribution, and it is possible to limit injected material entering the systemic circulation with the use of a tourniquet. The bladder similarly is a urothelial-lined organ, accessible for delivery of gene therapy vectors through a urethral catheter, with a consciously controlled, long dwell time for transfer of vector across the urothelium.

Table 91.1 Summary of the advantages and disadvantages of the most commonly used gene therapy vectors

	Advantages	Disadvantages
<i>Viral</i>		
Retrovirus	High rate of uptake Stably integrated; expression maintained in daughter cells Can affect both dividing and non-dividing cells	Non-specific integration/potentially mutagenic
Adenovirus	High rate of uptake	Immunogenic Needs to be readministered to maintain expression
Adeno-associated virus	High rate of uptake Specific integration into chromosome 19 Can affect both dividing and non-dividing cells	Immunogenic Limited length of insert
<i>Nonviral</i>		
Naked DNA plasmid	Easy, large-scale production Low immunogenicity	Low uptake rates Short persistence of vectors

In both the bladder and the penis, the main effector tissue for organ function is the smooth muscle (SM). Although both the endothelium and urothelium may have a modulating role in organ physiology, it is the SM tissue that is the final pathway of organ function. After the gene has entered into the nucleoplasm, it is important to note that SM cells have a low rate of division, so that a cell carrying the vector expresses the gene for a long time (i.e. months).

TARGETING SPECIFIC CELL TYPES

One of the advantages of the penis is the isolated nature of the organ, limiting the distribution of transfer agents and thereby unwanted expression of genes in other tissues that may cause side-effects. The specificity of gene expression also may be determined by the use of tissue-specific promoters, which is potentially a more significant problem with internal organs of the urogenital system, such as treatments aimed at bladder dysfunction.⁷ The most frequently used promoters are viral, for example, cytomegalovirus promoters. Viral promoters have the advantages of being smaller, stronger, and better understood than most human promoter sequences. However, the use of a tissue-specific promoter may limit expression of a gene to a tissue of interest, and thus may decrease the chance of side-effects from spurious expression of genes in non-target tissues. We recently developed a tissue-specific expression system in which the *Slo* gene is expressed from a SM actin promoter⁸ construct, restricting expression of the gene of interest (in this

case, *Slo*) to SM tissue, even if the gene is taken up by other cell types where expression may not be required or may even be deleterious.⁹ Alternatively, endothelial-specific promoters restrict expression to endothelial tissue.¹⁰ The potential advantage of using native human promoters is that there is less tendency for them to be silenced than the viral promoters.⁸

CURRENT TARGETS FOR ERECTILE AND BLADDER DYSFUNCTION

The regulation of bladder and penile function is a neurovascular process that relies on concerted action of the nervous system, the vascular system, the bladder, the urothelium, and SM tissues.¹¹ Most pathologic conditions of the urogenital system can be considered disruptions in one of the several pathways that regulate SM tone. The target of gene therapy in correcting urogenital pathologic features is to express genes that compensate for the altered expression in pathways regulating SM tone.^{12–14}

Ultimately at the biochemical level, normal SM tone is achieved through a balance of biochemical pathways that together regulate contraction or relaxation of the SM via myosin-driven actin filament sliding. The central regulator of SM contraction is the state of myosin light chain (MLC) phosphorylation. Contractile stimuli lead to an increase in intracellular calcium ($[Ca^{2+}]_i$) activating the intracellular calcium concentration-calmodulin-dependent MLC kinase (MLCK). This in turn phosphorylates the 20 kDa regulatory MLC of SM myosin (SMM) at Ser¹⁹ and shows a direct

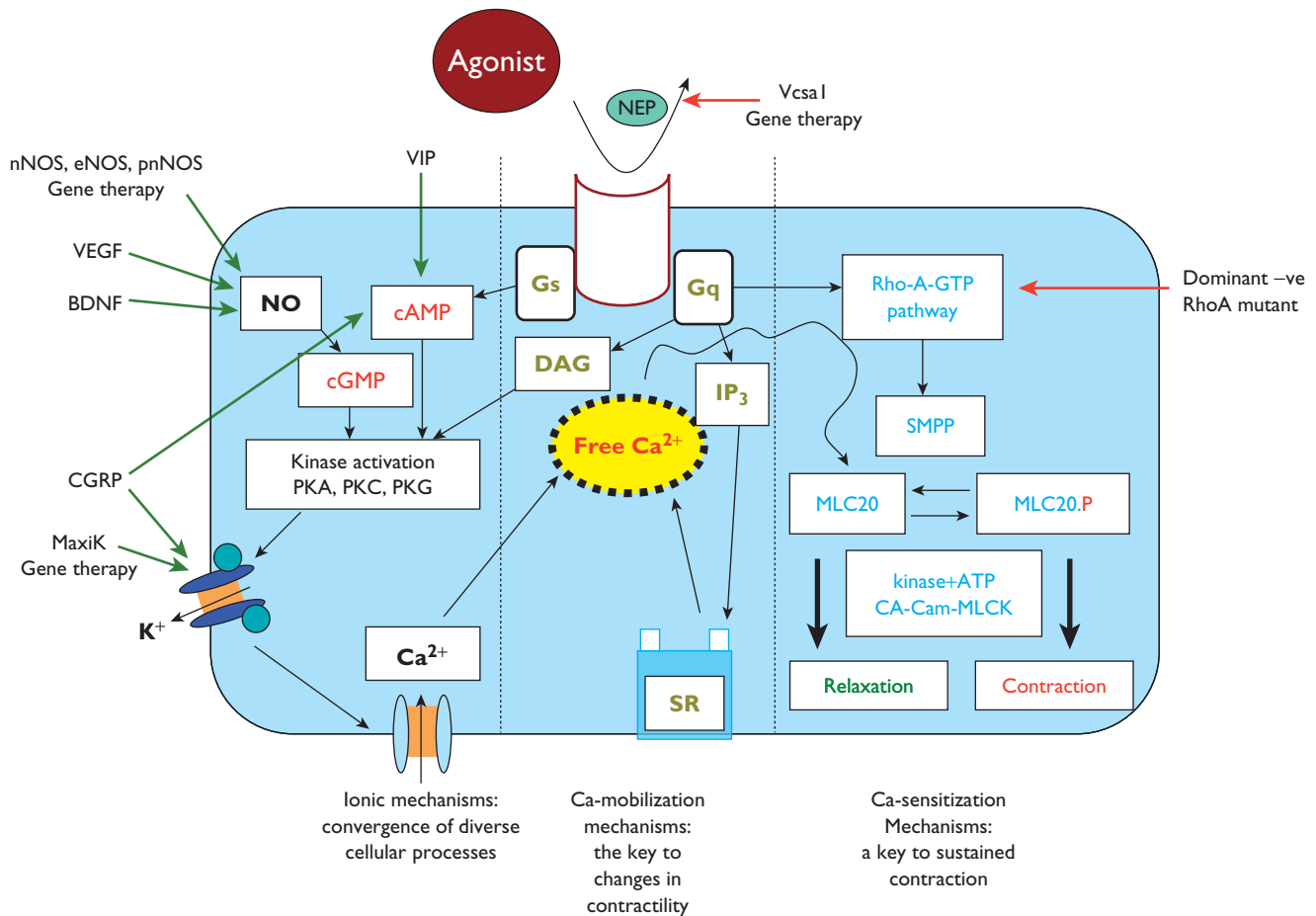


Figure 91.3 Illustration of the pathways leading to smooth muscle relaxation and the targets for gene therapy. BDNF, brain-derived neurotrophic factor; NO, nitric oxide; PKA, protein kinase A; PKC, protein kinase C; PKG, protein kinase G; SMPP, smooth muscle myosin phosphatase; VEGF, vascular endothelial growth factor; VIP, vasoactive intestinal peptide; cAMP, cyclic adenosine monophosphate; cGMP, cyclic guanosine monophosphate; NO, nitric oxide; nNOS, endothelial nitric oxide synthase; pnNOS, penile neuronal nitric oxide synthase; PKA, C, G, protein kinase A, C, G; VEGF, vascular endothelial growth factor; BDNF, brain derived neurotrophic growth factor; CGRP, calcitonin gene related peptide; SR, sarcoplasmic reticulum; DAG, diacylglycerol; GS, G-proteins; Gq, G-protein q; IP₃, inositol-triphosphate; SMPP, smooth muscle protein phosphatase; MLCZO, myosin light chain ZO; MLCK, myosin light chain kinase; Ca-cam, calcium-calmodulin; Vcsa1, variable coding sequence protein a1; NEP, neutral endopeptidase.

correlation with an increase in actin-activated adenosine triphosphate hydrolysis and cross-bridge cycling needed for generation of force. Figure 91.3 shows some of the pathways activated by a relaxation stimulus, which causes the level of cytosolic calcium to decrease, thereby inactivating MLCK. The myosin is dephosphorylated by SMM phosphatase, leading to SM relaxation.

To initiate the process of relaxation, agonists binding to their membrane receptors activate secondary messengers such as cycline guanine monophosphate (cGMP). The secondary messengers coordinate several biochemical pathways, leading to a decrease in $[Ca^{2+}]_i$ and SM tone. One mechanism involves the

activation of protein kinases A, C, and G, which in turn activates the maxi-K potassium channels, causing membrane hyperpolarization, which inhibits L-type calcium channels. The currently available Food and Drug Administration (FDA)-approved oral treatments for ED are phosphodiesterase 5 (PDE5) inhibitors that act by increasing the amounts of the secondary messenger cGMP by inhibiting PDE5 conversion to GMP. Agonists can be removed from their receptors by the activity of membrane-bound neutral endopeptidases (NEPs), which reverses the stimuli that cause SM relaxation. These pathways are depicted in Figure 91.3 and represent the major targets for gene therapy.

NITRIC OXIDE SYNTHASE

The production of nitric oxide (NO) from arginine by the enzymatic activity of NO synthase (NOS) plays a pivotal role in penile erection.¹⁵ Endothelial NOS (eNOS) expression is downregulated in the penis with both aging and diabetes.^{16,17} The restoration of NOS activity therefore is an excellent goal for gene therapy of ED. Several groups have used gene transfer of different NOS isoforms (eNOS, nitric oxide synthase, and penile nNOS) into the penis and reported an improvement in erectile function in animal models.^{18,19}

GROWTH AND NEUROTROPHIC FACTORS

Brain-derived neurotrophic factor (BDNF) plays a role in neuron regeneration in the central and peripheral nervous systems.²⁰ Neuropathic changes occur in the corpora with diabetes, aging, and cavernous nerve injury, which prevent erection. It is hoped that expression of BDNF can reverse nerve damage and thereby restore erectile function.²¹

One of the sources of NO is from the activity of eNOS in the endothelial cells. Vascular endothelial growth factor (VEGF) stimulates endothelial cell growth and angiogenesis. Overexpression of the gene causing proliferation of the corporeal vascular endothelium therefore can lead to increased NO production and relaxation of corporeal SM.^{22,23}

RHO KINASE PATHWAYS

Activation of rhoA by guanosine diphosphate (GDP) generated by the binding of agonists to G-protein coupled receptors activates rho kinase, which in turn inhibits MLC phosphatase.²⁴ This in turn results in a net increase in tone in the corporeal SM tissue. This pathway represents a target for knockdown of expression, which thereby would cause SM relaxation.²⁵

NEUTRAL ENDOPEPTIDASE INHIBITORS

Neutral endopeptidases (NEPs) remove agonists from their receptors by proteolysis. Recently, it was reported that an endogenous inhibitor of NEPs, sialorphan, can enhance erectile function in the aging rat, presumably

by protecting and prolonging the activity of agonists that cause relaxation of the corporeal SM tissue.²⁶

CALCITONIN GENE-RELATED PEPTIDE

Calcitonin gene-related peptide activates adenylate cyclase to generate higher levels of cyclic adenosine monophosphate (cAMP), which in turn activates potassium channels. This results in hyperpolarization of the SM cells and inhibition of the L-type calcium channels (as depicted in Figure 91.3).²⁷

MAXI-K

The Maxi-K channel plays a role in the regulation of L-type calcium channels, regulating intracellular calcium and thereby SM tone (as depicted in Figure 91.3). Gene transfer of the gene encoding the Maxi-K channel has been proven effective in treating both diabetic and aging rat models of ED^{28–30} and is currently the only treatment for ED that has progressed to clinical trials.³¹ This potential therapy is discussed in more detail below.

BLADDER DYSFUNCTION

The mechanistic basis for increased detrusor contractility is not understood fully, but as with ED, often a significant SM function component exists. Several of the gene therapy approaches for treating bladder dysfunction therefore overlap with the treatment of ED.

Maxi-K

The growing experimental literature indicates that altered electrical properties of detrusor myocytes (i.e. expression of K⁺ and/or Ca²⁺ channels) may contribute to the cause of urge incontinence/bladder overactivity. Among the numerous K channel subtypes identified to date, the Maxi-K channels are believed to play a physiologically relevant role in detrusor myocyte function. Gene transfer experiments in which rats with partial urinary outlet obstruction received bladder instillation of 100 µg Maxi-K eliminated the obstruction-associated bladder hyperactivity without affecting any other cystometric parameter in a detectable manner.³² Presumably, expression of *hSlo* in rat bladder

functionally antagonizes the increased contractility normally observed in obstructed animals and thereby reverses bladder overactivity.

Herpes simplex virus nerve growth factor

Expression of β -nerve growth factor from cells infected with a non-replicating human HSV has been shown to prevent and reverse diabetic neuropathy and expression in the dorsal root ganglia, which appears to reduce diabetic cystopathy.³³

Herpes simplex virus preproenkephalin

One approach to reduce bladder pain has been to use expression of preproenkephalin using HSV vectors.³³

HUMAN GENE TRANSFER TRIAL FOR ERECTILE DYSFUNCTION

Recently, the first phase I human trial for the therapy of ED was completed.^{31,34} Use of gene transfer as a legitimate treatment for a non-life-threatening problem was addressed in a recent commentary by Arthur Caplan, Chair of the Department of Medical Ethics, University of Pennsylvania School of Medicine. He stated:

Dismissing erectile dysfunction out of hand as a condition for which risks ought not to be permitted in research undervalues the importance of medical efforts aimed at maintaining or restoring the quality of life of patients. And, disparaging safety trials involving subjects with erectile dysfunction also fails to address the question of what sorts of conditions and what organ systems are likely to be the most useful in understanding the utility and safety of various gene vectors and their potential for efficacy.

Erectile dysfunction is a serious medical problem. There are many men who decline life-saving surgery for prostate cancer when told that such surgery may leave them impotent. The degree to which this condition matters in relationships and to the individual self-esteem of persons is reflected in the surgical measures that men were willing to endure before the advent of pharmacological treatments for impotency.³⁵

For this trial, the cloned gene, *hSlo*, that encodes the α , or pore-forming, subunit of the Ca^{2+} -activated K^{+} potassium channel (Maxi-K) was used to improve

erectile function. The *hSlo* gene was cloned into a commercially available expression vector pVAX (Invitrogen, Carlsbad, CA) to construct *hMaxi-K*, the naked DNA construct used in this first human trial of gene transfer therapy for the treatment of ED.

This study was conducted in compliance with the Declaration of Helsinki, US Title 21 Code of Federal Regulations, and the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use (E6, Guidelines for Good Clinical Practice; a public presentation to the Recombinant DNA Advisory Committee (RAC) of the Office of Biotechnology Activity of the National Institutes of Health), and approval of an investigational new drug application was submitted to and approved by the Center for Biologics Evaluation and Research of the FDA. The protocol and participant and partner informed consent documents were approved by an institutional review committee and institutional biohazard committee. A data safety monitoring board approved each participant's entry.

Study design and patient population

This was an open-label, sequential four-arm, phase I study to evaluate the safety and tolerability of *hMaxi-K* in men with ED. The study was designed to evaluate a single administration of four escalating doses of *hMaxi-K* injected into the corpus cavernosum of the penis. Three men were treated at each of three dose levels, 500, 1000, and 5000 μg , and two were treated with 7500 μg . Dose levels for this safety study were selected based on the lowest range of *hMaxi-K* used in preclinical studies in rodents. The 7500 μg dose in an average 70 kg man was equivalent to 69 μg in a 650 g retired breeder rat (approximately 106 $\mu\text{g}/\text{kg}$ in both species), but well below the maximum 1000 μg dose used in the rat (approximately 1538 $\mu\text{g}/\text{kg}$, equivalent to 107 000 μg in a 70 kg man). Even at the highest dose administered in the preclinical trials (i.e. 1000 μg), no immune responses or other adverse effects were observed.²⁹

The participant population consisted of men more than 18 years of age with ED attributable to an underlying, stable medical condition but otherwise in good health. Men with ED secondary to aging as a solitary cause were excluded. Participants must have been in a stable monogamous relationship for at least 6 months and had experienced no successful sexual intercourse for 6 months before study entry without specific ED

therapy. They were eligible if they were unable to tolerate, did not wish to continue, or had unsuccessful results with prior therapy for ED. Participants agreed to use condom barrier contraception during the course of the study.

The primary objective of this study was the safety and tolerability of a single injection of *hMaxi-K* at four escalating dose levels. The procedures and tests included general and genitourinary physical examinations, blood pressure, heart rate, electrocardiogram, general blood electrolyte and liver chemistries, hematologic parameters, endocrine tests, thyroid profiles, and urine and semen analysis. Adverse events also were assessed and recorded at each visit.

The DNA of semen was tested for the presence of pVAX-*hSlo* plasmid using reverse-transcriptase PCR with primers specific to the plasmid. The sensitivity of the assay was determined to be in the range of 1 copy/ μ g of total DNA, as previously described.³⁶ The key secondary study objective was assessment of the effect of *hMaxi-K* on ED using the erectile function domain category of the International Index of Erectile Function (IIEF-EF).

Final *hMaxi-K* gene transfer product

Subcloning of *hSlo* into the commercially available, non-viral, closed-loop (circular), double-stranded piece of DNA (pVAX) creates the naked DNA plasmid (Figure 91.4). The *hMaxi-K* in phosphate-buffered saline was produced in an FDA-approved³⁷ facility (Althea Technologies, San Diego, CA) under good manufacturing practices conditions.

Appropriate doses were injected at a single site into the corpus cavernosum of the penis. For this first trial, maximum precautions were taken to prevent unwanted biodistribution of the gene product. The half-life of the gene in blood is approximately 30 minutes. As an additional precaution, a tourniquet Actis venous flow controller (Vivus, Menlo Park, CA) was placed at the base of the penis before injection of the gene product and remained in place for 30 minutes to ensure that the vector was largely limited to the penis.

The study was conducted from May 2004 through May 2006. Three men each were given the 500, 1000, and 5000 μ g doses, respectively, and two men were given the 7500 μ g dose. The mean age of the study population was 59.0 ± 10.6 years (range 42–80). The primary cause of ED in six of the participants was diabetes and/or cardiovascular related, two participants

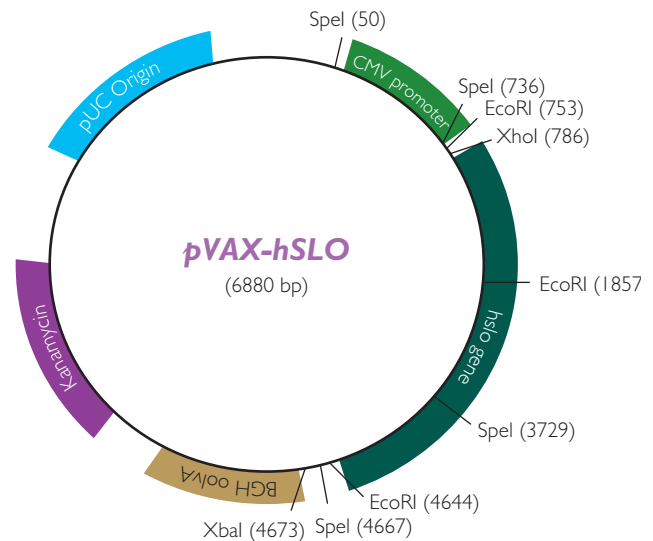


Figure 91.4 Illustration of the *hMaxi-K* plasmid construct, a double-stranded naked plasmid DNA molecule carrying the human cDNA encoding the gene for the α , or pore-forming, subunit of the human smooth muscle Maxi-K channel *hSlo*. CMV, cytomegalovirus.

had unspecified organic causes, one participant had sustained a fracture of the penis, one participant had undergone a radical prostatectomy, and one participant was diagnosed as psychogenic (i.e. erectile domain score on the IIEF of 12), but no discernible physical cause of ED. Participants were taking concomitant medications appropriate to their diagnoses in addition to ED, for example, hypertension, diabetes, and hypercholesterolemia medications. The duration of ED ranged from 1 to 20 years. The mean baseline IIEF-EF score was 6.8 ± 4.05 ; nine participants were categorized as having severe ED and two participants were categorized as having moderate according to standard classifications.³⁷

Polymerase chain reaction semen testing

There was no detectable evidence of *hMaxi-K* in semen down to the 1 copy/ μ g of the total DNA level in any participant at any of the visits.

Primary study endpoint: safety

No post-transfer events were considered related to the gene product transfer by the two investigators. No participants reported any discomfort from the injection

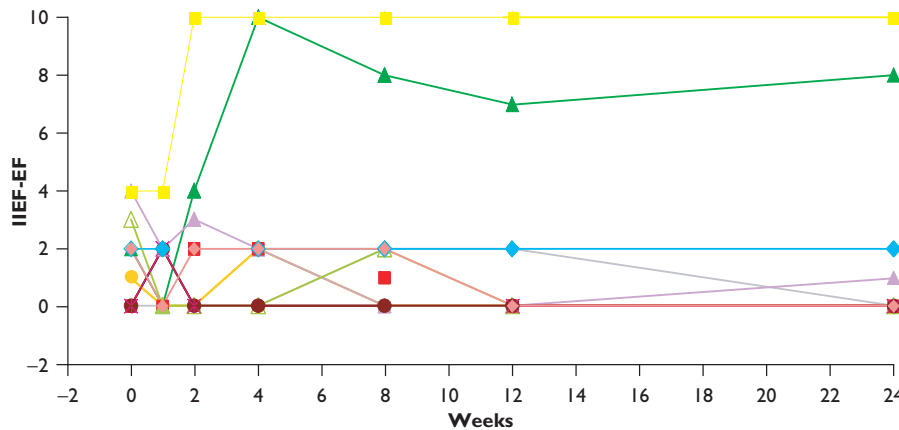


Figure 91.5 Graph depicting the erectile function subdomain response of the patient IIEF subdomain (items 3 and 4) over time to the four doses of *hMaxi-K*.

and no local physical events related to the injections were observed.

No clinically significant changes were seen in the general or genitourinary physical examinations during the study. No emergent transfer-related cardiac events were noted or reported during the study, and no significant changes in electrocardiogram results as determined by shift analysis (no normal-to-abnormal occurrences) were observed with the exception of the atrial flutter in one participant considered unrelated to treatment.

No clinically significant changes were seen in the mean values at the end of the study or at any of the interim study visits. In addition, no clinically significant changes from normal to abnormal in any blood chemistry, endocrine, hematology, or urinalysis values were seen at any visit for any participant. Mean systolic and diastolic blood pressures as well as heart rates did not show notable changes over time in each dose group. However, individual participant values varied from visit to visit and no clinically significant pattern of changes was evident. Therefore, no adjunctive therapies or changes in therapy were required.

Secondary study endpoint: efficacy

A decrease in mean scores at each dose was observed after 1 week. Mean scores for the two lower dose groups (500 and 1000 μ g) fluctuated around the baseline score throughout the 24 weeks of the study. However, improvements in the mean IIEF-EF scores were observed for the two higher dose groups beginning 2 weeks after transfer. Improvements were maintained in both groups through the 24 weeks of study. Figure 91.5 displays the IIEF-EF scores for each participant at each visit.

The positive changes from baseline for most participants were small and did not indicate improvement by IIEF scoring. However, one participant given 5000 μ g and one participant given 7500 μ g showed notable improvement in their IIEF-EF scores beginning 2 weeks after transfer. The IIEF-EF score continued to improve (from severe to mild or to no ED) at 4 weeks, and the improvement was maintained through the 24 weeks of the study.

The question of how long the effect lasted was addressed in the testimonial of the participant in the trial who received 5000 μ g *hMaxi-K*. The letter was written approximately 1 year after he received gene transfer.

The Replacement Gene

When I enter the Gene program for ED, I could not keep an erection. Viagra and the other ED drugs did not work for me. So when Dr Melman told me about this Gene program, I jump at the chance.

The Gene replacement worked well for me. It gave me an erection when I was aroused and it lasted long enough for my partner and me to have a climax. It worked for at lease six months, maybe longer.

I found that months after the Gene was injected and my participation in the program was over, I still could have an erection. Not a very hard erection but an erection none the less. And when I started using the Tri-Mix injections again, I only had to use a smaller amount than I did before the Gene injection (20 cc down from 80 cc).

I feel that if I had a higher dose of the Gene my erection would have been even harder and the effects would have lasted longer. I had no side effects.

8/24/06

Gene transfer therapy, particularly with vectors that do not incorporate into the genome, is extremely promising for prevention of the effects of aging and acquired diseases. Gene transfer focused on ion channel therapy in the SM of organs such as the penis and bladder offers a promising new treatment strategy.

Unique anatomic and ultrastructural features of the penis may account for the positive in vivo gene transfer results. Gap junctions located in the membranes of apposing SM cells of the penis provide the ultrastructural feature that allows rapid cell-to-cell propagation of second messengers after cellular activation by a variety of vasoactive compounds.^{31,38–40} The function of gap junctions in the penile corpora recently was reviewed.⁴¹ In the presence of gap junctions, non-viral gene therapy offers an attractive opportunity to achieve appropriate therapeutic response while minimizing adverse effects. K channels are critical for contraction and relaxation of the SM of the penis as well as other hollow organs such as the bladder, gut, and blood vessels. They alter membrane potential and excitability of SM cells by modulating Ca^{2+} influx through L-type voltage-dependent Ca^{2+} channels. The amount of Ca^{2+} that enters the cell through these channels is a major determinant of the free intracellular calcium levels inside the SM cells, which in turn determines the degree of SM cell contraction. The Maxi-K channel, that is, the large-conductance, calcium-sensitive K channel, is prominent among the K channel subtypes in corporeal SM cells. Increased Maxi-K channel activity is associated with corporeal SM cell relaxation and penile erection. The need for rapid, robust, and syncytial corporeal SM cell relaxation to obtain and maintain an erection is the basis for the use of K channel therapy in the treatment of ED.⁴⁰ Intracorporeal administration of *h*Maxi-K presumably increases expression of the Maxi-K channel in SM cells, which, with appropriate stimuli, will generate increased efflux of K^+ across the cell membrane, resulting in enhanced cellular hyperpolarization, and thus, decreased entry of Ca^{2+} ions.

The results of the phase I trial, although limited in scope and not placebo controlled, established that the technology of injecting recombinant DNA of a specific gene into a target organ to treat a specific problem, i.e. ED, could be accomplished. Future placebo-controlled and expanded trials are now indicated and planned. The next phase II trial will be a multiarmed, placebo-controlled, trial. A subset of the men will have repeat dosing of the *h*Maxi-K. If successful, the evolution of gene therapy for the

treatment of non-lethal but disabling disease will allow medicine to enter a new era.

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92 Ureteral tissue expansion

Georges-Pascal Haber, Jose R Colombo Jr, and Inderbir S Gill

INTRODUCTION

Tissue substitutes for reconstructive procedures of the urinary bladder, such as augmentation cystoplasty, are needed in a variety of acquired and congenital pediatric and adult urologic diseases. Amongst the various self-tissue substitutes such as buccal mucosa, scrotal skin, pericardium, or allograft tissues which can be used for a variety of urologic reconstructive procedures, only vascularized intestinal segments have been successful as regards reconstructive surgery of the urinary bladder.¹⁻⁵ However, use of intestinal segments in urinary tract reconstruction is associated with significant potential disadvantages, including metabolic complications, complicated infections, stone and tumor formation, and a variety of surgical risks associated with bowel surgery.¹ These disturbances are exaggerated in patients with compromised renal function, and in children.

Although it is difficult to estimate the total number of surgical cases performed in the US in which such excessive substitute tissue is needed, a recent article from a single pediatric hospital reported their experience with 483 cases of bladder augmentation during 25 years.⁶ The disadvantages of using intestinal segments in urinary tract reconstruction include metabolic changes, mucus production, high incidence of early and late surgical complications, and stone/tumor formation.¹ These disturbances may be exaggerated in patients with compromised renal function, and in children. In a search for more suitable tissue for bladder reconstruction, a variety of sources have been explored.^{1-5,7} The majority of these sources are still considered experimental, lacking any meaningful long-term clinical or experimental follow-up results.

Expansion of native skin has been successfully employed in various surgical disciplines such as breast reconstruction, craniofacial surgery, and plastic reconstructive surgery in patients with extensive burns.⁸ The expanded, new tissue, created by chronic stretch, replicates the morphometric and functional characteristics of the native tissue. A large body of literature

has been accumulated to explore the mechanisms involved in tissue expansion in response to chronic stretch. This literature demonstrates that the mechanisms behind the principle of stretch-induced cellular growth involve a network of several integrated cascades that include growth factors;⁹⁻¹⁴ extracellular, cytoskeletal and transmembrane structures;¹⁵⁻¹⁹ ion channels;²⁰⁻²² protein kinases;²³⁻²⁵ second messenger systems;^{26,27} and transcriptional factors.²⁸⁻³⁰

PATHOPHYSIOLOGY

Chronic stretch-induced tissue expansion is accompanied by increased expression of several growth factors and receptors that may contribute to cell proliferation and tissue remodeling required for expansion. In smooth muscle cells, these proteins include members of the transforming growth factor (TGF), epidermal growth factor (EGF), basic fibroblast growth factor (bFGF), platelet-derived growth factor (PDGF), and nerve growth factor (NGF) families.⁹⁻¹⁴ In bladder smooth muscle cells, mechanical stretch increased expression of heparin-binding EGF-like growth factor (HB-EGF) and one of its receptors, ErbB1, resulting in inhibition of apoptosis.¹⁰ Stretch also induced production of NGF by urinary tract smooth muscle cells,¹¹ and lower urinary tract obstruction induced hypertrophy of bladder afferent and efferent neurons that appeared to require increased NGF expression.¹² The latter finding supports the hypothesis that obstruction-induced tissue expansion induces remodeling of the neural networks.

Stretch-induced tissue expansion also involves extracellular matrix production, which is required for stretch-induced cell proliferation.⁹ In vascular smooth muscle cells, mechanical strain-induced fibroblast growth and extracellular matrix production were accompanied by increased expression of TGF- β 1 and inhibited by a TGF- β 1 neutralizing antibody.¹³ Rapid tissue expansion also may injure ureteral tissue more seriously than slow expansion, with associated ischemia and

inflammation. TGF- β 1 may be the main regulating factor for both the repair process and inflammatory response. We observed 2–3-fold increases in TGF- β 2 expression in porcine chronic expanded versus native ureteral tissues.³¹

Chronic tissue expansion has also been shown to induce angiogenesis, with associated ischemia, which in turn can stimulate production of vascular endothelial growth factor (VEGF).¹⁴ Ischemia induced by tissue expansion may also determine the degree of any ensuing fibrosis. In our preliminary study, no change in VEGF expression was observed in the expanded ureteral tissue.³¹ It should be noted that all of the above-cited literature regarding mechanisms of stretch-induced tissue remodeling pertains to cutaneous (skin) tissue expansion on cultured cells.

VISCERAL TISSUE EXPANSION IN URINARY TRACT

Tissue expansion techniques have also successfully been used in genitourinary tract tissues in the experimental setting.^{31–34} In 1996, Lailas et al initially reported chronic ureteral expansion for subsequent open ureterocystoplasty in a rabbit model.³² Ten rabbits underwent unilateral ligation at the ureterovesical junction and ipsilateral nephrectomy. A silicone catheter was placed into the proximal ureter and connected to a titanium injection port, which was placed subcutaneously at the level of the costal margin. Two weeks later a saline-antibiotic was injected in the port daily, limited by the pressure in the system. Within 6 weeks, the ureter was opened longitudinally on the anterior aspect, reconfigured into a 'U' shaped patch, anastomosed to the bladder and covered with an omental flap. A suprapubic tube was placed for 10 days after the procedure. After 6 months the animals were sacrificed. The cystogram showed a mean increase of 260% in the bladder capacity. Urodynamic studies were compatible with a low pressure, high capacity bladder. In 1998, Ikeguchi et al³³ performed chronic segmental ureteral expansion in eight pigs. A latex balloon was located in the distal ureter inserted through the renal parenchyma in an open surgical procedure. A 10 Fr Malecot nephrostomy was also placed. Daily ureteral dilatation (150–1000 ml) was performed with 1–50 ml daily over a period of 2–4 weeks, with no anesthesia required. After this an open ureterocystoplasty and reconstruction of the ipsilateral ureter were performed. A transurethral catheter was maintained for 1 week. Cystograms revealed an increased

bladder capacity. The animals were sacrificed after 4 weeks, and the histologic sections showed preservation of ureteral architecture with epithelial regeneration. In 2003, we initially reported a completely minimally invasive approach for chronic ureteral balloon expansion followed by laparoscopic augmentation ureterocystoplasty in a survival porcine model.³¹

Although the potential for ureteral tissue expansion in the context of urinary tract reconstruction has been preliminarily explored, none of the investigations have taken the issue far enough to explore the cellular and molecular mechanism involved in visceral tissue expansion and remodeling.

Encouraged by the above principles and potential usefulness of expanded ureteral tissue, we have pursued development and proof of concept of a methodology that would enable us to obtain excess ureteral tissue with minimally invasive surgical techniques. The expanded ureteral tissue can be used in open or laparoscopic surgical techniques in a variety of reconstruction applications for the lower urinary tract. Further, our preliminary studies have provided stimulus for pursuit of biologic markers possibly responsible for visceral tissue remodeling.

DESAI STUDY

The study was performed in 35–40 kg female farm pigs, after approval from the Animal Research Committee of our institution. The initial five animals were used to develop the prototype design and insertion technique of the ureteral expansion balloon, its inflation schedule, and the technique of laparoscopic ureterocystoplasty. Subsequently, five animals entered the survival study.

Methods

Percutaneous insertion of ureteral expansion balloon

All five chronic animals underwent unilateral (right three, left two) percutaneous insertion of the ureteral expansion balloon (Microvasive, Natick, MA), a dual-channel balloon catheter: one for inflation, and the other for proximal nephrostomy drainage (Figure 92.1). Initially, a 5 Fr open-ended ureteral catheter was inserted cystoscopically into the ipsilateral renal collecting system. The animal was then positioned prone, and percutaneous renal access was obtained under fluoroscopic guidance. A 0.035 inch Glide-wire

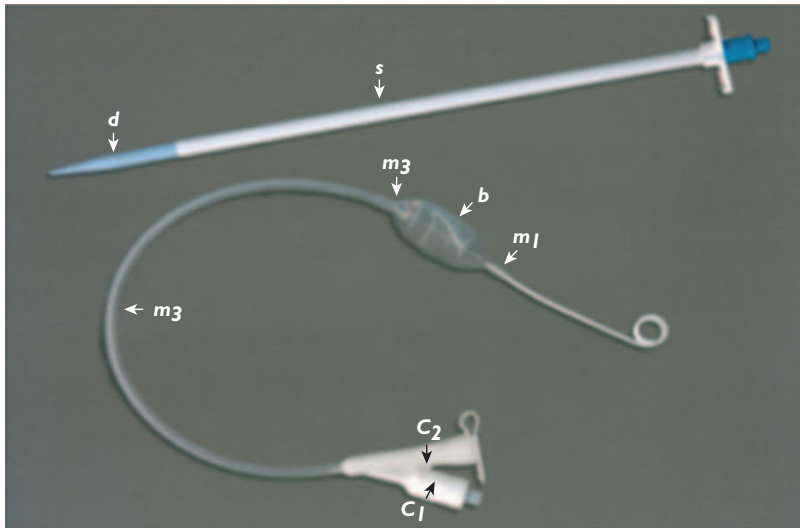


Figure 92.1 Ureteral expansion was performed using a novel silicone balloon TUEC catheter having two channels: a smaller channel to inflate balloon (c1) and a larger fenestrated channel to drain kidney (c2). The 14 Fr shaft has multiple holes to facilitate proximal urinary drainage. The balloon (b) has a radiopaque marker (m1 and m2) at either end to facilitate fluoroscopic confirmation during placement. Additional radiopaque marker (m3) on shaft immediately proximal to last drainage hole should lie within kidney. The terminal end of catheter is fashioned into a pigtail to facilitate retention in bladder. A single-step dilator (d) is used to position 20 Fr peel-away sheath(s) within renal collecting system.

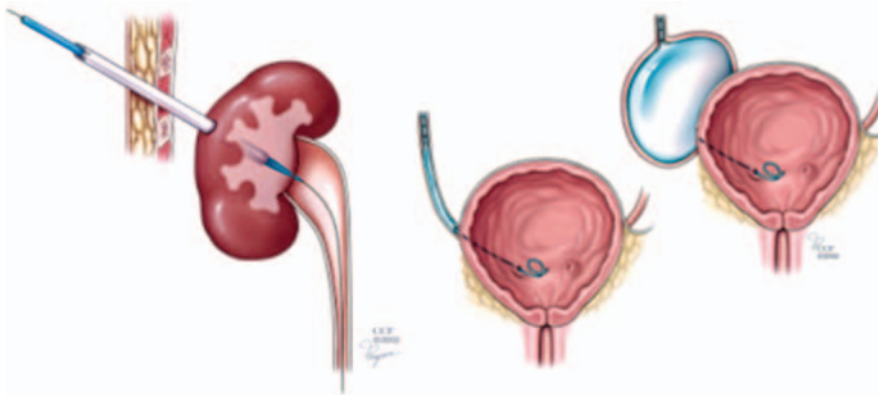


Figure 92.2 Procedures of percutaneous insertion of TUEC, and inflation of balloon. The deflated balloon is positioned in juxtavesical ureter. (Left) Incremental progressive inflation of balloon causes chronic expansion of juxtavesical ureter. (C) Expanded juxtavesical ureter. Note laterally based vascular supply to expanded ureteral segment from internal iliac vessels. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

(Microvasive) was manipulated antegrade down the ureter and retrieved through the bladder, and the open-ended ureteral catheter was removed. Using an antegrade 5 Fr ureteral catheter, the Glide-wire was replaced with a 0.035 inch Amplatz Superstiff guidewire (Microvasive). The percutaneous tract was dilated using a single-step dilator, and a 20 Fr peel-away sheath was positioned in the renal pelvis. A 21 Fr 10 cm ureteral dilatation balloon (Uromax; Microvasive) was used to dilate the entire ureter in a step-wise fashion over a period of 2 minutes to facilitate subsequent passage of the novel expansion device. The adequately lubricated balloon expansion catheter was gradually manipulated antegrade into the ureter over the Superstiff guidewire (Figure 92.2A). The balloon, flanked by radiopaque markers, was positioned in the juxtavesical ureter and distended with 2.5–3 ml of contrast medium to secure it in position (Figure 92.2B). The excess proximal length of the catheter exiting the animal's back was tunneled subcutaneously so that only the inflation and drainage ports were visible outside the skin.

Chronic ureteral expansion

Starting the day after placement of the ureteral expansion balloon, the ureter was gradually dilated by daily incremental instillation of a dilute (1:4) contrast solution.

Ureteral expansion was monitored radiologically every 7–10 days (Figure 92.3).

Laparoscopic augmentation ureterocystoplasty

Laparoscopic ureterocystoplasty was performed in all five animals after 3–4 weeks of ureteral expansion. All procedures were performed using a four-port transperitoneal approach with the pig under general anesthesia. Initially, the ureteral balloon was completely deflated, and the amount of fluid aspirated was measured. The balloon was subsequently refilled with the same amount of dilute antibiotic solution to facilitate intraoperative identification and to prevent intraoperative spillage of potentially infected fluid should inadvertent puncture of the balloon occur intraoperatively. After

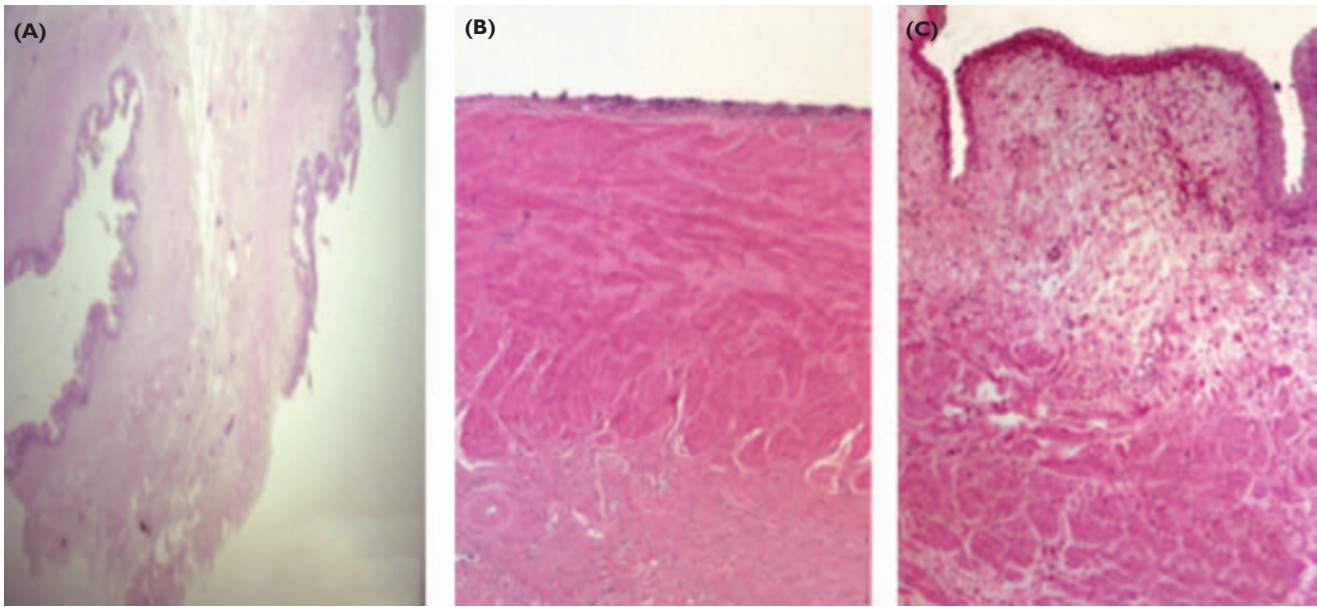


Figure 92.3 Light microscopic examination of (A) normal ureter, (B) tissue-expanded ureter which reveals muscle hypertrophy and hyperplasia, and variable inflammatory infiltrate, and (C) native bladder. Note that the expanded ureter (B) more closely resembles the thickness of the bladder wall (C) than the normal ureter (A).

port placement, the pelvic organs were examined laparoscopically. The expanded ureter was identified as a readily visible bulge adjacent to the urinary bladder. The medial peritoneum overlying the expanded ureter was incised to expose the ureteral wall. The fallopian tube and ovary on the ipsilateral side were mobilized away from the ureter. The bladder was mobilized by dividing the medial umbilical ligament and the superior vesical pedicle and incised laterally in a longitudinal fashion from just above the ureteral orifice up to the dome. The ureteral orifice and intramural ureter were preserved. Whereas in the initial two animals, the bladder dome was not excised, in the latter three, approximately 80% of the bladder was removed. The medial wall of the expanded ureteral segment was then incised using a J-hook monopolar cautery electrode, thus opening the expanded ureteral segment medially. Care was taken to minimize any mobilization of the ureter, thus maintaining intact the laterally based vascularity of the expanded ureter (Figure 92.4). The length, site, and orientation of the ureteral incision was tailored to correspond to the bladder defect (Figure 92.5). After the ureteral incision was completed, the balloon was deflated and the catheter removed. The in-line tissue-expanded ureteral patch was then anastomosed to the bladder in a running fashion using 2-0 Vicryl sutures on a CT-1 needle with freehand intracorporeal laparoscopic suturing and knot-tying techniques (Figure 92.6). After the posterior wall was sutured, an

18 Fr red rubber urethral catheter was inserted antegrade into the urethra through the bladder neck. The anterior wall was then sutured to complete the augmentation ureterocystoplasty. A 22 Fr Malecot suprapubic catheter was left indwelling and brought out through the suture line in the initial two animals only. A 22 Fr tube drain was positioned in the prevesical space in all five animals and brought out through a port site. The animals were returned to the chronic animal care facility.

Oral antibiotics were administered until urethral catheter removal. The suprapubic catheter was removed after 7 days, and the urethral catheter was removed after 14 days if not spontaneously expelled earlier. The drain, if not spontaneously expelled, was removed a day after the urethral catheter was removed. All animals underwent laboratory, radiologic, urodynamic, and histologic investigations (Table 92.1). Additionally, transmission electron microscopy of the expanded ureter and measurement of VEGF and TGF- β 2 in expanded ureteral tissue were performed in selected animals. Animals were sacrificed at 15 days ($n = 1$), 1 month ($n = 1$), 2 months ($n = 1$), and 3 months ($n = 2$).

Results

Percutaneous insertion of ureteral expansion balloon

Percutaneous insertion was technically successful with satisfactory balloon placement in all five animals. The

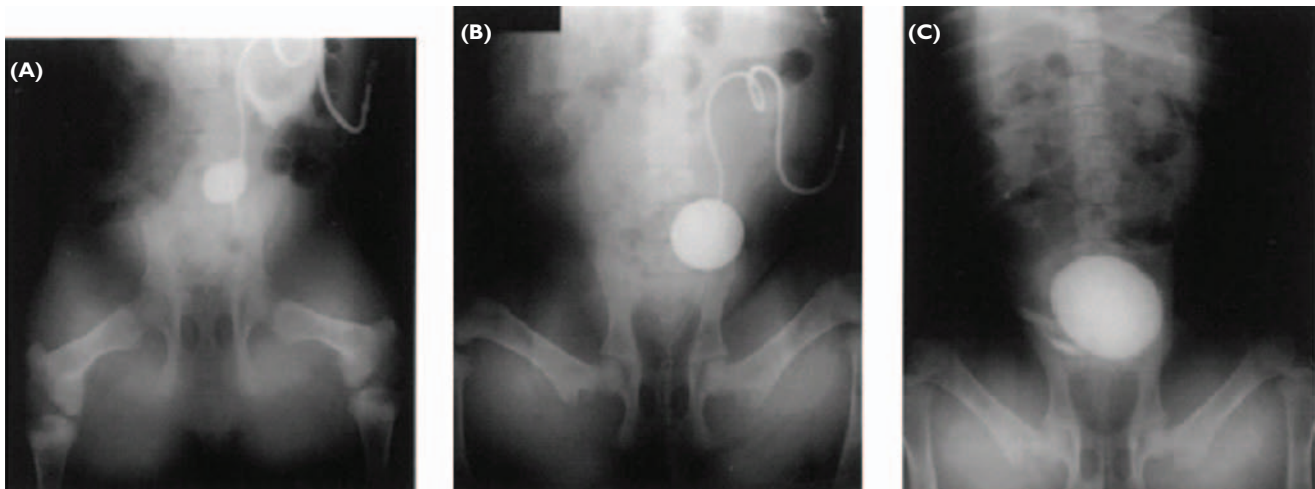


Figure 92.4 Plain radiographs of abdomen document progressive ureteral expansion. (A) At 1 week with 12 ml volume. (B) At 2 weeks, volume in balloon increased to 46 ml. (C) At 25 days just prior to augmentation ureterocystoplasty with 140 ml in the balloon.

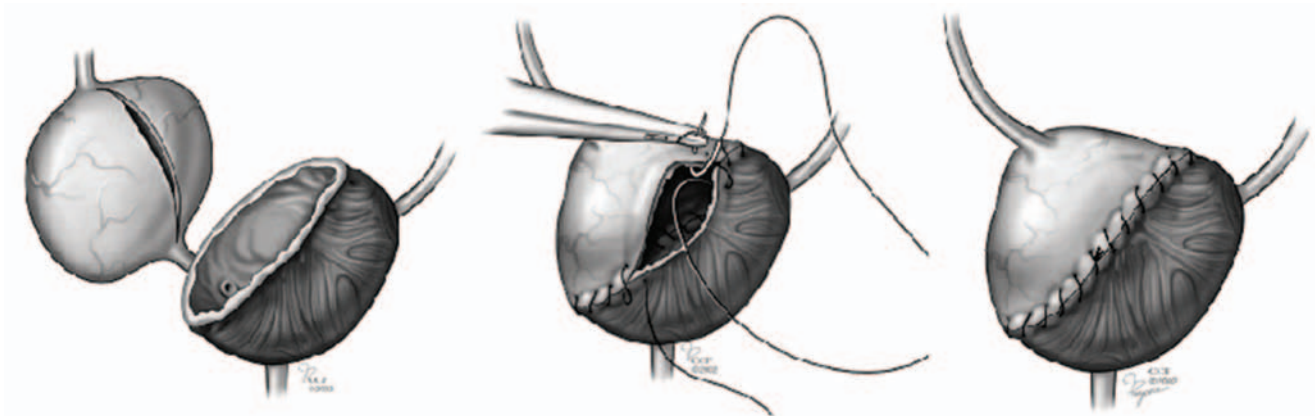


Figure 92.5 Steps during the laparoscopic ureterocystoplasty. Reprinted with permission of The Cleveland Clinic Center for Art & Photography © 2008. All Rights Reserved.

mean operative time required for balloon insertion was 52 ± 6 minutes, and there were no complications (Table 92.2).

Chronic ureteral expansion

All five animals underwent successful ureteral expansion over a mean of 25 ± 1.4 days (Table 92.3). The mean final volume of the ureter was 177.1 ± 41.3 ml. The mean volume of fluid instilled was 12.7 ± 0.9 ml in the first week, 38.4 ± 4.3 ml in the second week, 66.2 ± 17.4 ml in the third week, and 59.8 ± 28.4 ml in the fourth week. The mean daily inflation volume

was 1.8 ± 0.1 ml in the first week, 5.5 ± 0.6 ml in the second week, 11.3 ± 2.5 ml in the third week, and 16.1 ± 1.8 ml in the fourth week. All five awake animals readily tolerated the daily incremental instillation of dilute contrast solution without apparent pain or discomfort.

Radiologic volumetric assessment of the ureteral balloon during the phase of ureteral expansion was commensurate with the amount of fluid instilled. We did not note any complications during ureteral expansion. Proximal urinary drainage through the fenestrated channel of the ureteral expansion catheter was adequate in all five animals.

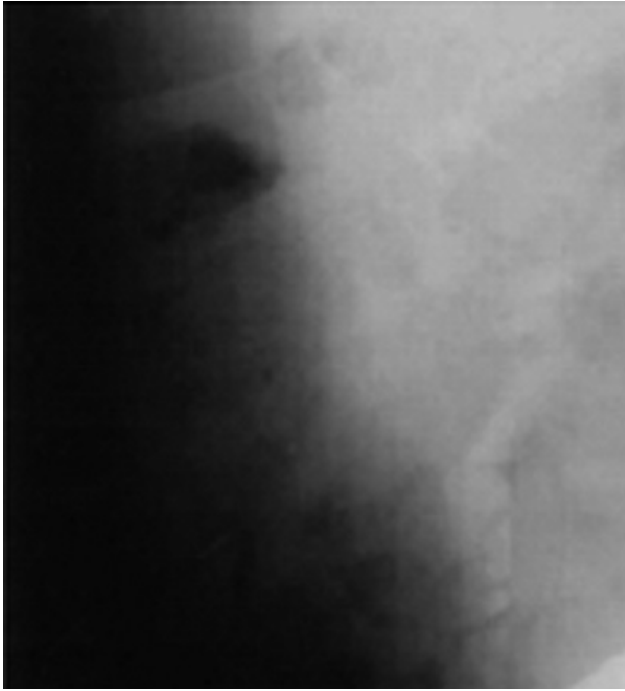


Figure 92.6 Cystogram performed immediately prior to autopsy at 3 months. Augmented bladder reveals capacity of 600 ml. There is grade II reflux in the right ureter.

Laparoscopic augmentation ureterocystoplasty

Laparoscopic ureterocystoplasty was technically successful in all five animals without need for open conversion in any case. The mean operative time was 156 ± 41.1 minutes (range 115–210 minutes), and the mean estimated blood loss was 29 ± 16 ml (range 10–50). One animal had a small-bowel serosal tear, which was readily suture repaired laparoscopically. Some periureteral adhesions were encountered in the vicinity of the expanded ureter, which could readily be lysed laparoscopically. Intraoperatively, at the time of ureterocystoplasty, the expanded ureter appeared thick and highly vascular, with areas of urothelial denudation. Intraoperative instillation of saline through the urethral catheter at the end of the ureterocystoplasty revealed a watertight anastomosis in all five cases. Postoperative complications were seen in two animals: lower ureteral obstruction and pyelonephritis with urosepsis.

Urodynamic, cystography, and cystoscopy data

Over a follow-up ranging from 15 days to 3 months, the mean bladder capacity was 574 ± 221.3 ml (range 380–940). The Pves at maximum capacity was $14 \pm$

Table 92.1 Investigation schedule

	Timing
<i>Laboratory</i>	
Complete blood count	Prior to balloon insertion
Metabolic profile, urinalysis	Prior to augmentation
Ureterocystoplasty and culture	Prior to euthanasia
<i>Radiologic</i>	
Plain film	Weekly during balloon inflation
	Prior to augmentation ureterocystoplasty
Cystogram	At 1-month follow-up
	Prior to euthanasia
<i>Intravenous urogram</i>	Prior to euthanasia
Urodynamics	Prior to euthanasia
Cystoscopy	At 1-month follow-up (N 5 2)
	Prior to euthanasia
<i>Histology</i>	
Light microscopy	During augmentation cystoplasty
	At euthanasia
Transmission electron microscopy	During augmentation cystoplasty (N 5 2)
Tissue cytokine assay (VEGF and TGF- β 2)	During augmentation cystoplasty (N 5 5)*

*Seven tissue biopsies were obtained from the five animals at the time of augmentation ureterocystoplasty for cytokine assay. VEGF, vascular endothelial growth factor; TGF- β 2, transforming growth factor β 2.

Table 92.2 Intraoperative data

Mean time for balloon insertion (min)	52 ± 10.6 (range 39–68)
Mean time for bladder augmentation (min)	156 ± 41.1 (range 115–210)
Estimated blood loss (ml)	29 ± 16 (range 10–50)
Subtotal cystectomy performed (n)	3
Ureteral stenting (n)	2
Urethral catheter (n)	5
Suprapubic catheter (n)	4
Open conversion (n)	0
Intraoperative complications (n)	Serosal bowel tear repaired laparoscopically (1)

4.5 cmH₂O (range 8–20), and bladder compliance was 71.7 ml/cmH₂O (range 35.3–188). Uninhibited detrusor contractions were not evident on urodynamic evaluation in any of the five animals (Table 92.4). Cystography

Table 92.3 Balloon inflation data

Animal	Time (days)	First week		Second week		Third week		Fourth week		Final volume (ml)	
		Mean inflation volume** (ml)	Daily volume instilled† (ml)	Mean inflation volume** (ml)	Daily volume instilled† (ml)	Mean inflation volume** (ml)	Daily volume instilled† (ml)	Mean inflation volume (ml)	Daily volume instilled (ml)	Actual	Estimated
1	23	1.6 (0.5–3)	11.5	6.4 (3.5–10)	45	10 (10–10)	50	14.5 (14–15)	29	135.5	120
2	24	1.7 (0.5–3)	12	4.9 (3.5–9)	34	10 (10–10)	50	14.6 (14–15)	44	140	132
3	26	1.8 (1–3)	13	5 (3.5–9)	35	10.8 (10–15)	65	18.6 (15–20)	93	206	200
4	26	1.9 (0.5–3)	13.5	5.6 (4–10)	39	13 (12–15)	91	17.4 (15–20)	87	230.5	216
5	26	1.9 (0.5–3)	13.5	5.6 (4–10)	39	12.5 (12–15)	75	15.3 (15–16)	46	173.5	170
Mean	25	1.8	12.7	5.5	38.4	11.3	66.2	16.1	59.8	177.1	167.6

*Estimated amount of fluid in balloon at end of expansion process.

†Actual volume of fluid aspirated from ureteral expansion balloon immediately prior to augmentation ureterocystoplasty. This volume was slightly less than the anticipated volume. There are two possible explanations: (1) some unmeasurable fluid loss may occur during balloon inflation because of sudden movement of the animal; and (2) some fluid may not be completely aspirated from balloon.

‡Total volume of fluid introduced into balloon in a week divided by number of days injected. Although inflation was performed daily, a few days were skipped for logistical reasons.

*Total volume of expansion achieved during week.

revealed ipsilateral reflux in four renal units: grade II in one animal, grade IV in two animals, and grade V in one animal (Figure 92.7). At autopsy, one renal unit demonstrated lower ureteral obstruction and therefore showed no reflux on cystography. There was no contralateral reflux in any renal unit. In all four refluxing units, the refluxed contrast drained from the kidney immediately after the bladder was emptied, thereby ruling out any ureteral obstruction. Additionally, the cystogram did not reveal contrast extravasation in any case.

Cystoscopy was performed in all animals at 1 month and at autopsy. By 1 month, the bladder revealed a fully regenerated mucosa in four animals; one animal sacrificed at 15 days still had patchy areas of denuded mucosa.

Laboratory data

Laboratory examination revealed minimal metabolic alterations in four animals. One animal that developed pyelonephritis and urosepsis had evidence of azotemia, hyponatremia, hyperkalemia, and acidosis (Table 92.5). The mean serum creatinine concentration was 1.3 ± 0.2 mg/dl at baseline, 0.9 ± 0.2 mg/dl at bladder augmentation, and 2.0 ± 0.9 mg/dl at euthanasia.

Autopsy data

At autopsy, the ureteral patch appeared well vascularized, and the ureterocystoplasty suture line was healed in all five animals (Figure 92.8). The ipsilateral renal parenchyma appeared grossly normal in three cases, with pre-euthanasia intravenous urography (IVU) revealing prompt opacification with mild hydronephrosis. One animal with a lower ureteral obstruction revealed thinning of parenchyma and poor function on IVU. At autopsy, the obstruction was found to be the result of flimsy synechia formation at the junction where the upper, normal caliber, ureter entered the expanded ureteral segment. The animal with pyelonephritis and urosepsis had a grossly scarred kidney that was non-functioning on IVU.

Histologic data

Light microscopic examination of biopsies of the expanded ureter obtained at the time of augmentation cystoplasty revealed muscle hypertrophy and hyperplasia, mucosal atrophy, and variable inflammatory infiltrate.

Electron microscopic data

Transmission electron microscopy performed on the ureteral tissue obtained at the time of laparoscopic

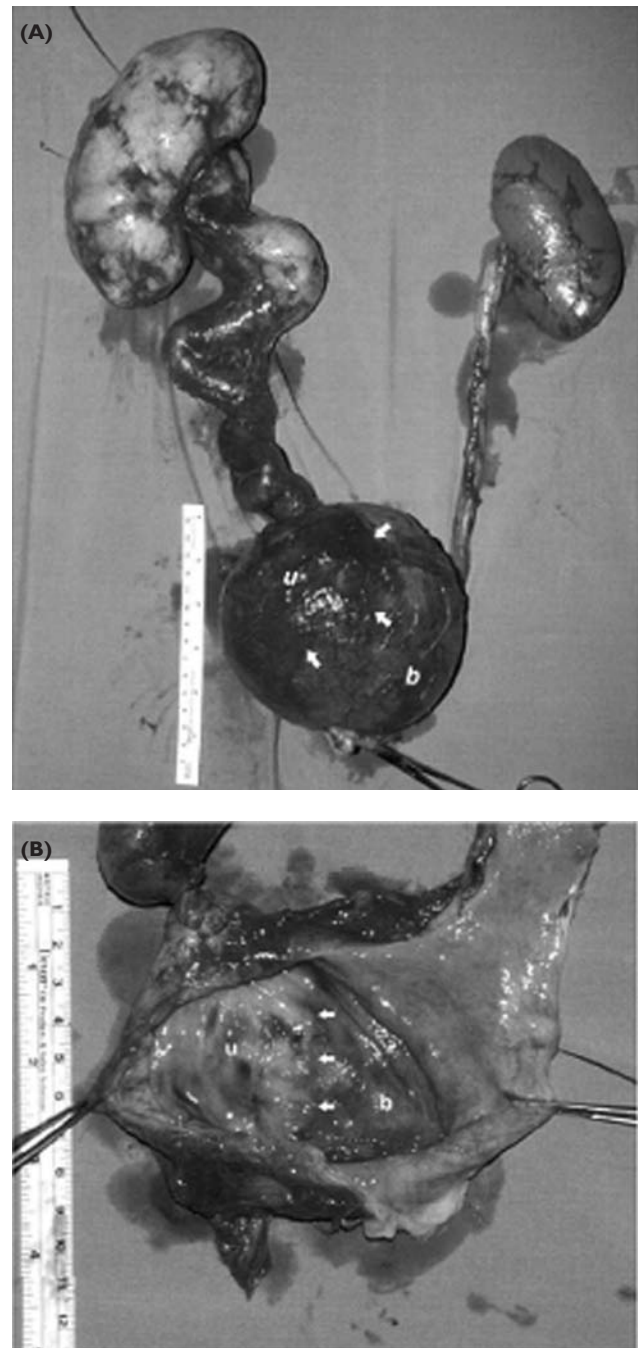


Figure 92.7 Autopsy photographs. (A) augmented bladder and both renal units. Healed suture line between expanded ureteral patch (u) and native bladder (b) is seen (arrows). (B) Interior of augmented bladder shows demarcation (arrows) between expanded ureter (u) and native bladder (b). Notice complete epithelialization of expanded ureteral patch.

augmentation revealed cellular evidence consistent with muscular hypertrophy and hyperplasia (Figure 92.10).

Table 92.4 Radiologic data

Animal	Follow-up (weeks)	Cytogram*			Urodynamics†			
		Subtotal (80%) cystectomy	Ipsilateral reflux (grade)‡	Anastomotic leak?	Bladder capacity (ml)	Resting	Full capacity ml/cmH ₂ O	Involuntary bladder contractions
1	2	No	2	No	600	3	20	Absent
2	4	No	4	No	380	2	12	Absent
3	8	Yes	—	No	940	3	8	Absent
4	12	Yes	4	No	430	4	12	Absent
5	12	Yes	5	No	520	6	18	Absent
Mean	—	—	—	—	574	3.6	14	—

*Cystographic examination was performed at 1 month (N 5 3) and at autopsy (N 5 5) by injecting contrast through a urethral catheter. In all refluxing renal units, obstruction was ruled out by documentation of prompt drainage of contrast from the collecting system.

†Urodynamics, in the form of filling cystometrograms, was performed in each animal immediately prior to autopsy. The animal was anesthetized and placed supine on the table. The bladder was filled through a 6 Fr urethral catheter, and intravesical pressure was recorded through a separate 6 Fr urethral catheter connected to manometer tubing. Parameters recorded included total bladder capacity, resting and end filling pressures, bladder compliance, and involuntary detrusor contractions.

‡No animal developed contralateral reflux.

Table 92.5 Serum biochemical data

	Prior to ureteral balloon expansion	Prior to augmentation cystoplasty	Prior to euthanasia
Mean serum creatinine (mg/dl)	1.3 ± 0.2 (1.1–1.4)	0.9 ± 0.2 (0.7–1.1)	2.0 ± 0.9 (1.4–3.4)
Mean serum potassium (mEq/l)	139.4 ± 3.3 (136–143)	135.5 ± 7.0 (127–144)	132.5 ± 9.7 (119–140)
Mean serum sodium (mEq/l)	4.3 ± 0.2 (4.1–4.5)	4.4 ± 0.2 (4.1–4.6)	4.7 ± 0.6 (4.1–5.4)
Mean serum chloride (mEq/l)	97.2 ± 3.4 (93–102)	95.5 ± 6.5 (88–103)	88 ± 18.9 (66–100)
Mean serum carbon dioxide (mEq/l)	27 ± 3.3 (24)	27.8 ± 0.5 (27–28)	24 ± 5.7 (16–19)
Mean anion gap	15.2 ± 3.9 (9–19)	12.3 ± 1.0 (11–13)	18.3 ± 11.4 (10–35)
Mean hemoglobin (mg/dl)	11.6 ± 0.3 (11.3–12)	9.6 ± 1.0 (8.7–10.9)	10.3 ± 2.6 (8.8–14.1)
Mean hematocrit (%)	39.8 ± 2.0 (37.7–42.3)	32.0 ± 3.4 (29.1–35.8)	35.3 ± 8.1 (27.7–16.8)

Growth factor assay data

Preliminary data on growth factor expression in expanded ureteral tissue obtained and snap frozen at the time of augmentation ureterocystoplasty revealed a 2–3-fold increase in TGF- β 2 (median 44 pg/ml; range 27–49) over controls (normal ureter 16 pg/ml) (Table 92.6). There was no increase in VEGF expression in the expanded ureteral tissue compared with control samples.

CLINICAL STUDY (GILL ET AL, UNPUBLISHED DATA)

Following our laboratory experiments and upon availability of the opportunity in two outside medical centers, we performed this procedure in three patients outside the US, in India ($n = 2$) and Brazil ($n = 1$), with the approval of the ethical committee at each local institution. Clinical data from these patients have been encouraging, supporting our laboratory data. Specifically, we treated two women and one man, aged 14, 65, and 54 years, respectively. Each patient suffered from a non-compliant bladder with reduced capacity (range 15–150 ml).

Operative time for the laparoscopic augmentation ureterocystoplasty ranged from 2 to 3 hours, and blood loss was 25–50 ml. Each patient commenced oral intake on the same day and ambulated within 24 hours. Hospital stay ranged from 6 to 8 days. There were no infections or other complications at any stage of this study. Postoperatively bladder capacity increased significantly to 250–280 ml at 2-month follow-up. The first patient completed 2-year follow-up with durable success. All three patients experienced significant, even dramatic, improvement in voiding symptoms, and the renal function is well preserved.

CLINICAL IMPLICATIONS

This could potentially eliminate the use of bowel (and its attendant morbidity) in urinary tract reconstruction. Potentially, such a bladder substitute could have mucosal, myogenic, and neurogenic attributes that approximate those of a functionally intact urinary bladder. Our proposal represents a concerted effort at establishing and developing this novel field of visceral tissue expansion.

The search for the ideal tissue substitute for bladder augmentation is ongoing. To date, intestinal segments remain most commonly used tissue for bladder augmentation. Although the results of augmentation cystoplasty using various bowel segments have generally been acceptable, these tissues are associated with absorptive metabolic changes, mucus production, and stone formation, the magnitude of which is dependent on the length and segment of bowel used.³⁵ Significant research in the past few decades has focused on alternative tissue substitutes for urinary tract reconstruction. These have included tissue-engineered materials,³⁶ xenografts such as small intestinal submucosa (SIS),³⁷ and techniques such as autoaugmentation³³ and de-epithelialized bowel.³⁸ Some of these techniques, although promising, have either been insufficiently durable or require considerable refinement.

Augmentation ureterocystoplasty has been reported, with encouraging long-term urodynamic results, and limited, if any, metabolic changes. However, the amount of ureteral tissue needed to provide a urodynamically acceptable bladder augmentation can be obtained only in a patient with a large megaureter. Therefore, currently, augmentation ureterocystoplasty is limited to the occasional patient with a megaureter and a non-functioning kidney who requires bladder augmentation.

Thus, although the potential for ureteral tissue expansion for urinary tract reconstruction has been demonstrated, further characterization of the biology of ureteral expansion and refinement of technique are necessary prior to its clinical application. The Desai study was designed specifically to address the following crucial issues: (1) the feasibility of percutaneous insertion of the ureteral expansion device; (2) the efficacy of this novel balloon in expanding the ureter to the desired volume while simultaneously providing adequate drainage of the renal unit; (3) a safe and reliable time line schedule and regimen for ureteral balloon expansion; (4) the technical feasibility of performing laparoscopic augmentation ureterocystoplasty using the tissue expanded ureter; and (5) the biologic nature of the expanded ureteral tissue and its efficacy in providing a urodynamically adequate bladder augmentation in a survival porcine model.

Postoperative complications occurred in two animals. One animal, whose ureter was unstented, developed lower ureteral stenosis, hydroureteronephrosis, and poor ipsilateral renal function, and the other animal had pyelonephritis with urosepsis. At autopsy, the animal with lower ureteral obstruction revealed flimsy adhesion formation at the junction of the expanded

ureter with the proximal normal caliber ureter. There was no transmural fibrosis on histologic examination of the stenotic area. This obstruction probably represents cross-healing of the opposite ureteral walls following mucosal denudation during the expansion process and can potentially be avoided by stenting at the time of augmentation ureterocystoplasty until re-epithelialization is complete.

Our survival porcine study demonstrates that progressive, incremental ureteral tissue overexpansion can be carried out safely and reliably with a percutaneously placed expansion balloon. This ureteral expansion is well tolerated and can be performed over a 3–4-week period to create a sizable reservoir for bladder augmentation. The expanded ureter is thick and vascular, and reveals histologic and electron microscopic features of durable ureteral smooth muscle hypertrophy and hyperplasia. This expanded tissue can be used laparoscopically to augment the bladder. Such augmented bladders possess good urodynamic properties over a 3-month follow-up period.

Concerted research in this arena will lead to further development of this novel field of visceral tissue expansion.

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93 Nerve regeneration: grafts, conduits, and strategies

Arthur L Burnett

INTRODUCTION

In the burgeoning hybrid discipline of neurolourology, neuromodulatory therapy for erectile dysfunction has come to be recognized as a scientifically and clinically important subject area. Such therapy aims to restore and promote the neurologic health of the lower genitourinary tract, threatened by disease or injury including iatrogenic surgical trauma. Many urologists know of the pioneering modifications of radical prostatectomy described by Walsh approximately 25 years ago, which showcased the innovation of ‘nerve-sparing’.¹ The advance established the importance of maintaining the structural integrity of autonomic, erection-mediating cavernous nerves coursing adjacent to the prostate when performing radical prostatectomy to maximize postsurgical erectile function outcomes. Importantly, the new approach to the procedure was shown not to compromise the oncologic objectives of the surgery. In current practices when the surgery is performed according to principles of anatomic dissection with the application of cavernous nerve preservation techniques, postoperative erectile function recovery rates have certainly improved compared with those of the prior surgical era in which complete erectile dysfunction was universally observed postoperatively.^{2,3}

The advance of anatomic radical prostatectomy with cavernous nerve preservation techniques is also credited with paving the way for more recently explored neuroprotective and nerve regenerative therapeutic strategies for erectile preservation. In concept, these strategies refer to both surgical and medical therapeutic innovations directly relevant for neurogenic erectile dysfunction. At the same time, such strategies may offer therapeutic benefit for various functions in the pelvic region which involve nerve-dependent actions. In the example of applying neuromodulatory strategies for pelvic surgery such as radical prostatectomy, other conditions that may be improved include urinary continence and even alleviation of postsurgical neuropathic pain.

The purpose of this chapter is to review emerging concepts in the neurogenically based clinical

management of erectile dysfunction with an emphasis on neuromodulatory strategies suited to the realm of radical pelvic surgery. The review encompasses current developments as well as promising possibilities for the future, with the understanding that significant advances are urgently needed to improve upon current methods for preserving erectile function in the setting of pelvic surgery. Indeed, substantial impetus exists to bring this area of study forward at this time, in light of the fact that many men today continue to experience some degree of erectile impairment in the long term following radical prostatectomy and require erection aids despite modern modifications of the surgery.⁴ Key support for the notion of bringing forward neuromodulatory interventions for radical pelvic surgery is the knowledge that neuropathy of the penis frequently accounts for the functional loss in this clinical context.^{5,6}

CAVERNOUS NERVE GRAFT RECONSTRUCTION

Basic concepts

Consistent with traditional precepts for the surgical treatment of injured peripheral nerves, reconstructive procedures have been used to re-establish cavernous nerve structural continuity. These procedures have ranged from primary neurorrhaphy to interposition grafting as indicated for nerve defects which are too large for direct repair or would be repaired undesirably under excessive tension.⁷⁻⁹ Reconstructive procedures have been applied for injury of peripheral somatosensory nerves as well as that of autonomic nerves including the facial nerve, the brachial plexus, and autonomic ganglia of internal organs. Success using grafting procedures in general relates to the integrity of the end organ, the duration of denervation, the length of the grafted segment, the diameters of the grafted and recipient nerves, and the achievement of a tension-free anastomosis.⁸

This intervention has been introduced to the urologic arena in the form of cavernous nerve interposition

grafting for radical prostatectomy. In concept, when cavernous nerves are resected during the surgery, as required for oncologic control because of locally advanced disease, the retained portions of these nerves are feasibly reconstructed using an interposition graft thereby allowing a maximum number of regenerating axons to progress through the site of injury and reconnect with the erectile tissue. An additional possible feature of a natural nerve graft is that it serves as a source of Schwann cells and growth factors, which supposedly contributes toward recipient nerve regeneration.^{9,10}

Clinical reports

The strategy of applying a nerve conduit for reinnervating the penis following cavernous nerve injury was initially investigated using animal models.^{11–13} Walsh subsequently initiated a randomized, blinded pilot investigation in humans interposing genitofemoral nerve grafts in six men at the time of radical prostatectomy, but he discontinued the investigation after failing to see any difference in erection recovery compared with six control patients after 5 years.¹⁴ Kim et al pursued the matter further advancing the use of autologous sural nerve grafting for this particular purpose.¹⁵ These investigators supported the feasibility of nerve grafting and conceived that this approach afforded the opportunity for recovery of erectile function to a better extent than in its absence. Their initial report found that among 12 preoperatively potent men who required bilateral excision of the neurovascular bundles at the time of radical prostatectomy and received bilateral grafting using the sural nerve, four (33%) recovered erections at 1 year compared with none of 12 concurrent controls without grafting.¹⁶

Kim et al further reported on their extended experience in 28 men evaluated at a mean interval of 23 months after undergoing bilateral sural nerve grafting.¹⁷ For this follow-up, 23 preoperatively potent men completed International Index of Erectile Function (IIEF) questionnaires, of which six (26%) achieved IIEF erectile function domain scores of 20, consistent with spontaneous, medically unassisted erections sufficient for sexual intercourse, and an additional four were able to perform sexual intercourse with the assistance of sildenafil.¹⁷ From this analysis, they calculated an overall potency rate of 43% (ten of 23 men). By comparison, a contemporaneous control group of 12 preoperatively potent men who underwent bilateral neurovascular bundle resection without nerve grafting produced a significantly lower IIEF erectile function domain score of 3.¹⁷

These same investigators next explored the concept of unilateral sural nerve grafting in men undergoing unilateral excision of the neurovascular bundles at radical prostatectomy. Their assessment was that graft replacement resulted in erection recovery to a better level than without grafting (78% versus 30%), and the results approximated their outcomes following bilateral nerve-sparing surgery (79%).¹⁸

Several other investigators have also reported on their use of nerve grafting in association with radical prostatectomy. Chang et al found that among 30 preoperatively potent patients who underwent bilateral resection of cavernous nerves and autologous nerve grafting 18 (60%) were confirmed objectively to have recovered spontaneous erectile ability and 13 (43%) were able to engage in sexual intercourse (seven unassisted and six assisted by sildenafil) at a mean follow-up of 23 months.¹⁹ Anastasiadis et al found that four (33%) of 12 preoperatively potent men who underwent bilateral sural nerve grafting for resected cavernous nerves after radical prostatectomy or cystoprostatectomy were fully potent (scoring more than 20 on the erectile function domain of the IIEF) at a mean follow-up of 16.1 months.²⁰ Nelson et al reported on 27 patients who underwent 32 genitofemoral nerve grafts, among which five patients received bilateral grafts.²¹ These investigators reported that 69% of preoperatively potent men, as confirmed by IIEF erectile function domain scores, were able to have sexual intercourse at a mean follow-up interval of 14 months.²¹

Surgical planning and technique

Among considerations for proceeding with nerve graft reconstruction unilaterally or bilaterally after radical pelvic surgery, one of the foremost is proper patient selection. Some patients with localized disease would seem to meet eligibility requirements based on the understanding that they are not candidates for anatomic cavernous nerve dissection and preservation, clearly a preferred approach when possible for affording opportunities for erection recovery following the surgery. The extent of or risk for local disease progression as suggested by the high grade tumor profile or characteristics of the tumor extending toward the cavernous nerves in these patients indicates that it would not be appropriate to offer cavernous nerve preservation techniques. At the same time, suitable patients for cavernous nerve grafting who require nerve resection should likely be predisposed to possess postoperative

erectile ability. Patients with poor quality erections preoperatively or those who had received neoadjuvant hormonal or radiation therapy would be considered suboptimal candidates for the intervention. In presenting the circumstances of the clinical presentation and surgical options, the surgeon should counsel the patient regarding the expectations and potential risks associated with nerve grafting.

The surgical technique requires the interposition of a nerve conduit to replace a cavernous nerve segment excised from its course adjacent to the prostate. Kim et al described their surgical technique,^{22,23} which has been similarly applied by others. The main steps are: (1) preparation and resection of the periprostatic neurovascular bundles (which contain the cavernous nerves), (2) harvesting the sural (or donor) nerve, (3) placement of the graft, and (4) completion of the vesicourethral anastomosis. Often, dual surgical teams are enlisted, including a urologic team to perform prostate removal and pelvic reconstruction, and a microsurgical team to perform the donor nerve harvest and nerve grafting.

Under general anesthesia, the patient is placed in the lateral decubitus position with the leg chosen for sural nerve harvesting positioned superiorly. A midline incision from the mid-calf to the ankle is made, followed by identification of the sural nerve at the lateral ankle distally and between the median and lateral heads of the gastrocnemius muscle proximally, the dissection is undertaken in a retrograde fashion. Although approximately 7–8 cm is routinely excised for unilateral grafting, enough nerve length can be obtained from one site for planned bilateral grafting. The harvested nerve graft is kept in moist saline gauze until its insertion in the pelvis.

After the patient is placed in the supine position, the radical prostatectomy is performed. Although the surgery entails cavernous nerve resection, it should nonetheless proceed with careful handling of the neurovascular bundle. Surgical loupe magnification is deemed to be a key requirement for identifying the distal anastomosis juncture particularly because of difficult visualization retropubically. Proximal and distal marking sutures placed at the time of neurovascular bundle resection are especially helpful to ensure a proper anastomosis. A bloodless field is optimal for preparing and carrying out the anastomosis, and some have advocated positioning the patient in the Trendelenburg (head down) position to lessen visual obscurity associated with blood accumulating in the deep pelvis.¹⁹ The harvested nerve graft is inserted and then anastomosed initially at the distal end and

subsequently at the proximal end using polypropylene microsutures (between sizes 6-0 and 8-0). To avoid nerve trauma and to ensure a tension-free anastomosis, the proximal end is frequently done after completion of the vesicourethral anastomosis. Some surgeons have advocated the creation of additional laxity in the graft to reduce tension that could occur with bladder distention.²⁰ Careful positioning of the postsurgical drain to avoid direct negative pressure on the nerve graft and its anastomoses is also recommended.

Several modifications of the standard surgical technique have been described. Some surgeons have applied intraoperative cavernous nerve stimulation reporting that it enables them to confirm the function and location of the recipient nerve.^{18–20,24} However, others have found that the nerve stimulator is relatively inaccurate in localizing the precise course of the neurovascular bundle.²⁵ Cavernous nerve grafting has been successfully applied when laparoscopic and robotic approaches are used to perform radical pelvic surgery.^{26–28} In addition to the sural nerve, alternative donor nerves have been successfully harvested and used including the ilioinguinal nerve and the genitofemoral nerve.^{14,21,29} The rationale for exploring these alternative nerve sources, even though they are less substantial in size than the sural nerve, is that their harvesting is viewed to cause less morbidity than that associated with sural nerve harvesting.

Critical analysis

Enormous enthusiasm exists to apply cavernous nerve graft reconstruction for patients undergoing radical prostatectomy and other pelvic surgeries as well. Clinical reports do indicate the feasibility of this intervention and its seemingly low morbidity. The objective is worthy: to maximize the nerve supply to the penis in situations when cavernous nerves must be removed in the course of radical prostatectomy for retaining sexual function postoperatively. Consistent with the understanding that the greater extent of surgically intact nerves results in better functional outcomes, reports in the literature uniformly describe better erectile function rates following the performance of bilateral cavernous nerve preservation than that associated with unilateral preservation surgery.^{6,30–32}

Several limitations of cavernous nerve graft reconstructive surgery have been posed. Immediately perceived is the issue that carrying out a more extensive surgery may result in added perioperative morbidity. This risk can be simply associated with the circumstance

of increased operative time, translating into greater likelihood of blood loss and even risks of prolonged anesthesia. Additional concern relates to the morbidity of donor nerve harvest. For the sural nerve, recognized risks include paresthesias involving the lateral aspect of the foot, local hematomas, local infection, chronic leg pain, delay in ambulation after surgery, and rare formation of neuromas or reflex sympathetic dystrophy.^{18,23} This constraint is seemingly overcome when alternative nerve sources such as the genitofemoral and ilioinguinal nerves are used.^{14,21,29} The investigators found these other nerve sources did not produce significant adverse sensory changes associated with the dermatomes of the harvested nerves.

The accuracy of nerve grafting in this situation is also a cause for concern. It is recognized that the neurovascular bundle is composed of many fine nerve structures along with the random arrangement of blood vessels, fascia, and fatty tissue. This anatomic basis constrains attempts to create an exact reconnection of the cavernous nerves. Furthermore, recent anatomic studies have demonstrated the diffuse fan-like arrangement of the cavernous nerve fibers which diverge particularly at proximal locations and its topographic variability among individuals.^{33–35} This arrangement would seem to limit an effective surgical reconnection of the nerve distributions which solely or predominantly subserve the neuronal input to the penis.

The biochemical properties of the nerves involved in cavernous nerve reconstruction also present a potential concern. The consequences resulting from grafting a peripheral somatic nerve to a mixture of sympathetic and parasympathetic nerves of the neurovascular bundle remain undefined.^{18,19} Because the sympathetic nerves of the neurovascular bundle serve an anti-erectile role and possibly contribute to erectile tissue contraction and penile atrophy postoperatively, nerve grafting in this situation possibly may hamper erection recovery. It is also important to appreciate principles of nerve regeneration which apply to this intervention. Despite the notion that the interposed nerve graft would hasten nerve-mediated erection recovery, the requirements of nerve regeneration via this conduit apply equally in this instance as for traumatized but intact nerves. Accordingly, consistent with the rate of nerve function recovery approximating 1 mm/day, the recovery process following cavernous nerve grafting may require 12–18 months to achieve functional reinnervation with erectile tissues.¹⁹ In this respect, the nerve conduit may correctly be thought of as a biologic scaffold for the basic process of cavernous nerve regeneration and not really a mechanism for rapid reinnervation of the penis.

An additional concern relates to whether cavernous nerve grafting is demonstrably effective. Current reports published at this time carry limitations, which may bias conclusions. These limitations include retrospective accrual of data, lack of randomized, concurrent controls, mostly small numbers of reported patients, and also limited time frames for follow-up in some series. Additionally, one may argue that many patients purported to have recovered erectile function with nerve grafting may have been disposed to this recovery on the basis of surgically retained cavernous nerve distributions. This possibility indubitably exists when unilateral nerve grafting is performed because of the presence of undamaged cavernous nerves contralaterally. Some degree of cavernous nerve preservation may also occur when bilateral nerve resection and grafting is performed. A possible scenario is that in dissecting the neurovascular bundle and preparing the nerve anastomosis the surgeon may partially preserve cavernous nerve fibers, whereas these fibers would have been certainly removed during a standard wide excision of periprosthetic tissue. Because of these potential problems, further study of this intervention remains necessary to discern its true benefit. Such study may ideally employ a study design which incorporates prospective data accrual, randomization of equally characterized, preoperatively potent patients to nerve grafting and non-grafting arms of treatment, application of validated assessment tools, and sufficient clinical follow-up.

Finally, a particular matter of consideration is the applicability of cavernous nerve grafting in the current era of increasingly early-stage prostate cancer clinical presentations. Without question, appropriately performed nerve preservation techniques are advocated over grafting procedures for radical prostatectomy when possible, since nerve-mediated erectile ability will most certainly be better postoperatively with intact than with grafted nerves.¹⁴ It would appear that the majority of surgical candidates for radical prostatectomy at present would be able to receive the surgery with cavernous nerve preservation according to oncologic principles. In this light, the most likely indication for nerve grafting is the presentation of a preoperatively potent man whose locally extensive cancer precludes cavernous nerve preservation.

It should be recognized, however, that the conditions of locally advanced disease could impact on the eventual success of cavernous nerve grafting. It is conceivable that these conditions may prompt the need for locally or systemically administered adjuvant or salvage therapies which would predictably devitalize the graft or otherwise result in erectile impairment

directly. In the series of Anastasiadis et al, five (50%) of ten patients who underwent radical prostatectomy had positive surgical margins, and three of the five with persistent disease receiving adjuvant external beam radiation or hormonal therapy reported having no erections.²⁰ Similarly, in another report, 44 consecutive patients with bilateral grafts were found to have an 11% cumulative recovery of erection allowing vaginal penetration at 5 years following surgery, and none of the patients who underwent external beam radiation for prostate cancer recurrence recovered any level of erectile function.³⁶ These real-life results further call into question the clinical utility of cavernous nerve grafting.

THERAPEUTIC PENILE NEUROGENESIS

Rationale

Neurogenesis is a developmental biology concept that refers to the growth and regeneration of neurons in organ systems. The concept pertains to the basic science of neurotrophic growth factors, neural development, neuroprotection, neural regeneration, and the prevention of neuronal cell death. It is fitting that neurobiologic strategies are now being brought to the clinical management of neurogenic erectile dysfunction and particularly the setting of prostate cancer treatment-associated cavernous nerve injury. These strategies adhere to the understanding that nerve development and reconstitution are linked with erectile tissue health and function.

Therapeutic avenues which can be introduced to the field of neuourology borrow from a range of neurobiologic studies conducted for assorted nerve injury contexts including peripheral nerve injury and spinal cord trauma. These avenues are practically categorized as being neuroprotective or nerve regenerative in effect. This schema fits ideally with the range of pathogenic mechanisms associated with nerve injury operating at cellular and molecular levels of neuronal tissue, and it specifies molecular neurobiologic targets related to nerve function recovery of potential therapeutic relevance. Neuroprotective interventions would be particularly useful to address a variety of possible mechanisms contributing to nerve injury including inflammation, oxidative stress, immunologic responses, ischemia, excitotoxicity, lipid peroxidation, free radical production, and apoptosis. Nerve regenerative interventions would conceivably consist of neurotrophic factor treatments, axonal outgrowth inhibitory stabilizer treatments, axonal reconstruction

with nerve guides or other neurotropic (nerve growth directional) substances, tissue engineering, stem cell therapy, and electrical nerve stimulation.

Clinical studies

At this time, the majority of advances in this scientific area have resulted from preclinical investigation with a significant use of experimental animal paradigms that mimic the clinical condition of radical prostatectomy. It should be acknowledged that animal models have offered tremendous insight into molecular mechanisms involved in cavernous nerve neuronal degeneration and regeneration. Rat studies of cavernous nerve injury, for example, have verified collagen infiltration and fibrosis of cavernosal tissue along with cavernosal smooth muscle destruction and apoptosis resulting from cavernous nerve injury.³⁷ Such studies have also served to identify the existence and functional relevance of neurotrophic factors in the penis.³⁷ Finally, animal models have provided useful tools to explore in vivo the pharmacologic and molecular therapeutic effects of a host of endogenous and exogenous substances for correcting neurogenic erectile dysfunction.³⁷

Relatively few clinical studies have been initiated thus far evaluating therapeutic prospects in this area for radical prostatectomy. These are presented briefly below.

Corticosteroids

Corticosteroids have been investigated preliminarily, after being introduced to this clinical arena following studies in other clinical contexts of nerve injury. The intervention is based on suggestions that corticosteroids would counteract inflammatory conditions resulting from surgical trauma. In one study, the corticosteroid methylprednisolone was systemically administered for a short course immediately following the surgery,³⁸ and in another betamethasone cream 0.1% was locally applied to the cavernous nerves at the time of surgery.³⁹ Neither treatment was found to be efficacious relative to the control situation consisting of no treatment at intervals up to 12 months postoperatively. While no complications were observed in these studies, support for the therapeutic benefit of corticosteroids in the setting of radical prostatectomy remains limited to date.

Immunophilin ligands

Immunophilin ligands, e.g. the immunosuppressant FK506 (tacrolimus) and its non-immunosuppressive

derivatives, have garnered major interest for this clinical purpose. Their potential utility has been amply bolstered at the preclinical level in which the ameliorative effects of such agents have been shown in animal models of cavernous nerve injury.^{40–43} The mechanism of action of these drugs for neuroprotection has remained elusive. Initial understanding was that these drugs operated as immunosuppressants and thus countered immune responses associated with cavernous nerve injury. This supposition was derived from the knowledge that the prototype agent FK506 is clinically used in circumstances of non-autologous organ transplantation to prevent graft rejection. However, scientific investigation has established that the mechanism of immunosuppression involving calcineurin inhibition is unrelated to the neuroprotective effects of these drugs, a premise underscored by the evidence that non-immunosuppressive immunophilin ligands are potent neuroprotectors.^{44–47}

Current thinking regarding the neuroprotective action of these drugs is that they operate through specialized receptor proteins precisely called immunophilins. Immunophilins, expressed surprisingly at 50-fold higher concentrations in nerve tissue than levels measured in immune cells, are thought to be the key molecular effectors for these drugs.^{44–47} The clinical attraction to apply these drugs for neuroprotection is heightened by scientific evidence showing that upregulated expression of immunophilins occurs in injured nerve tissue.⁴⁸ The implication of this observation is that these ligands administered in the face of nerve injury expectedly generate specific, localized effects and do not act elsewhere in the body, possibly causing undesired complications. Subsequent molecular effects likely involve downstream intracellular signaling processes. Recent studies have supported the activation of antioxidative mechanisms, in view of the evidence that immunophilin ligands have been found to cause glutathione upregulation.^{49,50}

To date, two controlled clinical trials have been initiated under pharmaceutical company sponsorship exploring the clinical utility of this therapy, one investigating the non-immunosuppressive immunophilin ligand GPI1485 (MGI Pharma Inc, Baltimore, MD) and the other investigating the prototype agent FK506 itself (Astellas Pharma Inc, Tokyo, Japan). Both trials represent multicenter, randomized, double-blind, placebo-controlled studies involving preoperatively potent men undergoing nerve-sparing radical prostatectomy. Both have sought to determine the therapeutic effects of immunophilin ligand therapy on improving erectile function recovery following this surgery relative to that without treatment. Because studying the

outcomes of radical prostatectomy requires extended intervals, both trials represent significant endeavors with requirements for long-term clinical follow-up. Completion of these trials with subsequent reporting of results is eagerly awaited. Demonstrations of clinical safety and efficacy would certainly propel the clinical use of this therapy. At a minimum, the trials should offer useful insight into the further development of such neuromodulatory strategies in the future.

Electrical nerve stimulation

Electrical stimulation of the cavernous nerves has been demonstrated to elicit erectile responses acutely during experiments in animal models and in human studies.^{51,52} Its application as a treatment for penile smooth muscle degeneration resulting from denervation injury has also been briefly examined. In a small trial consisting of 21 patients with erectile dysfunction who were consistently non-responsive to vasoactive pharmacotherapy, short courses of electromyostimulation administered directly to the corpus cavernosum subsequently produced improved spontaneous erectile function in four (19%) patients while another three (14%) became responsive to vasoactive drugs.⁵³

A pharmaceutical company sponsored clinical trial was recently conducted to explore the possible use of an implantable electrical stimulator to rejuvenate damaged nerves for patients undergoing radical prostatectomy (Advanced Bionics, Valencia, CA). This pilot study found that an electrode array device can be easily and efficiently placed in the pelvis adjacent to the cavernous nerves during radical prostatectomy and focal nerve stimulation can be safely administered using the device.⁵⁴ The objective of additional studies would be to define and implement a stimulatory protocol postoperatively that achieves improved functional nerve recovery.

Critical analysis

Although the concept of therapeutic neurogenesis for radical prostatectomy and other radical pelvic surgeries is relatively new, it is a welcome advance at this time. In many respects, this emerging therapy offers a timely adjunct to improve upon current rates of erectile function recovery which remain insufficiently met today despite the use of cavernous nerve preservation techniques when performing radical pelvic surgery. Quite likely, the very best technical proficiency for structurally preserving cavernous nerves will foreseeably remain imperfect in achieving prompt, consistent

erections in men undergoing surgeries involving prostate removal. This opinion is based on the known effects of cavernous nerve trauma which occurs unavoidably with the surgical dissection and removal of the prostate in the pelvis. Such trauma produces a phenomenon of at least temporary loss of nerve function (also termed neuropraxia). Therapeutics targeting the biochemical and molecular properties of these nerves would conceivably offer an appropriate next step in making major progress in this clinical arena.

Current advances in neurobiology as a general discipline suggest vast opportunities to apply neurobiologic therapies to pelvic surgery. However, careful scientific evaluation will be required before offering them for this purpose. Classic neurotrophins offer an example of the need to exercise caution in promoting potential therapeutics in this area. Results from prior clinical trials outside the urologic field have raised concern regarding the clinical safety of these agents. In phase II and III clinical trials for diabetic polyneuropathy and HIV-related neuropathy, nerve growth factor was shown to have questionable efficacy for ameliorating symptoms, and its administration was associated with painful sensory side-effects.⁵⁵ Similarly in clinical trials for treating amyotrophic lateral sclerosis, ciliary neurotrophic factor, brain-derived neurotrophic factor, and insulin growth factor-1 have also demonstrated limited therapeutic efficacy.⁵⁶ These results would suggest the limited utility of some neurotrophic compounds at least when systemically administered for treating the penile neuropathy associated with major pelvic surgery.

Prostate cancer and its surgical treatment present special circumstances for applying innovative strategies in neuromodulatory therapy. A potential major disadvantage is whether neurotrophic therapeutic offerings present mitogenic risks. This concern is relevant with respect to prostate cancer cells which may have escaped the organ at prostatectomy or existed as micrometastases prior to surgery. Adding to the concern is the actual evidence that classic neurotrophins and neuropeptide growth factors increase tumor invasiveness and enhance growth of prostate cancer cells in preclinical models.⁵⁷⁻⁵⁹ Importantly, it is noted that the non-immunosuppressant immunophilin ligand GPII046 was not shown to confer growth stimulatory effects on malignant prostate cells *in vitro*.⁶⁰ This finding further suggests the specificity of effect supposedly exerted by immunophilin ligand therapy while it also supports its safety in the setting of radical prostatectomy.

Notwithstanding their safety concerns, neurobiologic strategies may be advantageously brought to the clinical setting of radical prostatectomy. Because the

surgery is planned and the occurrence of the nerve injury is predetermined, it affords a definite opportunity for applying therapies which are truly neuroprotective. Another conceivable advantage is related to the circumstances of the perturbation as a local and controlled peripheral nerve injury. Accordingly, systemically diffusible therapy would not be required in this situation, and the therapy would not be required to penetrate particular anatomic barriers as would be the case for interventions directed toward brain and spinal cord injuries. For pelvic surgery, therapy could easily be applied directly in the pelvic region at the time of the surgery. Radical prostatectomy further offers a unique experimental paradigm to test and develop neurobiologic strategies in a general sense. The frequency with which the surgery is performed, its reproducibility, the predictability of nerve injury associated with it, its temporal characteristics in terms of the precise onset of the injury and a fairly well defined time line for nerve function recovery, and the availability of a measurable endpoint (erectile function restoration) to evaluate the success of the therapy are factors indicating the seemingly high usefulness of this paradigm for this purpose.

It is readily accepted that much more study is needed before advancing the utility of neurobiologic strategies for pelvic surgery. The specialty area is well represented by preclinical work, which has generated substantial momentum to bring this field of study forward clinically. As one would expect, therapeutic prospects will need to be subjected to rigorous evaluation in the form of standardized clinical trial methodology in order to establish their clinical safety and efficacy profiles.

SUMMARY

Undoubtedly, the ground swell of activity to establish neuromodulatory therapies for erectile preservation particularly for radical pelvic surgery is a well founded response to the compromised level of the functional outcome occurring commonly in this clinical arena. The retention of erectile function after pelvic surgery is predicated on both the structural and functional integrity of the penile nerve supply. Strategies to preserve and optimize this innervation in the face of injurious conditions have become a major priority. In an attempt to meet this charge, both interposition nerve grafting and neurobiologic interventions targeting the cavernous nerves have been advanced as the foremost approaches to address the problem. Much of the

progress associated with these approaches, however, is limited to suggestions of their applicability and feasibility. Definitive evidence of their clinical therapeutic benefit remains deficient at this time. Current work in the field should lead to improved definitions of their roles while they may also guide new evolutionary strategies in this field. A concept for the future is that various options, selected from a menu of neuromodulatory approaches, could be used for any pelvic surgical situation based on the circumstances of the surgery. Nerve regenerative guides and locally eluting polymers or wafers containing neurotrophic compounds placed in the vicinity of preserved or reconstructed cavernous nerves to any extent are examples of potential applications for the future. As indicated for any new developments in medicine, continued scientific investigation and controlled clinical trial outcomes assessments are invaluable for establishing the place of new advances in standard clinical practice.

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94 Image-guided surgery

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INTRODUCTION

Improvements in technology leading to increased and early detection of small tumors have resulted in complex decision algorithms for treating various genitourinary malignancies. This is particularly true when imaging can be combined with some type of therapeutic intervention. In the management of malignancies there is a growing interest in focal therapies or simple monitoring of disease through active surveillance. In both cases there is a critical need for accurate imaging of the organ in question.

Accurate detection of cancer foci through improved imaging has paved the way for a significant paradigm shift from radical treatment of cancer to relatively non-invasive forms of focal therapy.

OVERVIEW OF IMAGE-GUIDED TECHNOLOGIES

Ultrasound guidance

Ultrasound is a widely available, inexpensive modality that does not use ionizing radiation. It allows real-time visualization and hence is commonly used for image-guided procedures in various genitourinary lesions. Although ultrasound can guide interventions in most common genitourinary conditions, some specific indications that are suited for ultrasound guidance are aspiration of fluid from cystic lesions (Figure 94.1), transrectal prostate biopsy (Figure 94.2),¹ brachytherapy,² radiofrequency ablation of superficial and peripheral exophytic renal lesions, biopsy of renal lesions,³ and image-guided intervention in young and pregnant patients. Disadvantages of ultrasound are operator dependency, inability to visualize deeper structures, poor tissue characterization, and limited use in obese patients and patients with poor bowel preparation.

Computed tomography guidance

As computed tomography (CT) is becoming the primary imaging modality for most genitourinary lesions,

it has also become a useful tool to guide interventions.⁴ CT is used for guiding biopsies (Figure 94.3) and performing drainages as well as for radiofrequency ablation of malignant renal lesions.⁵ Its high spatial resolution allows visualization of important anatomic structures that need to be avoided while procedures are being performed.

Certain conditions in which CT is preferred over the other radiologic modalities are renal tumor biopsy (Figure 94.4), lymph node biopsy, and abscess aspiration. Disadvantages of this technique are the use of ionizing radiation (which is an important concern in children and pregnant women), no real-time view, and limited use in uncooperative patients.

Magnetic resonance guidance

Magnetic resonance imaging (MRI) allows very good soft tissue characterization but its use for image guidance is limited by its longer scan times, higher cost, limited availability, and stringent conditions for use of MRI-compatible biopsy instruments. Recently MRI guidance has been described for prostate biopsy⁶ and prostate brachytherapy.⁷

OVERVIEW OF MINIMALLY INVASIVE TECHNOLOGIES

Prostate biopsy

Prostate cancer diagnosis depends on pathologic diagnosis. In most cases prostate biopsy samples are obtained through a transrectal biopsy of the prostate. Although transrectal ultrasound (TRUS) of the prostate was described in the mid-1960s,⁸ it took about 20 years before TRUS became an integral part of prostate biopsy.⁹ Introduction of the random systematic sextant biopsy method further standardized TRUS-guided prostate biopsy.¹⁰ Recent literature suggests that a higher number of prostate biopsies would enhance the prostate cancer detection rate¹¹ and could be done safely and without increasing prostate biopsy morbidity.¹²

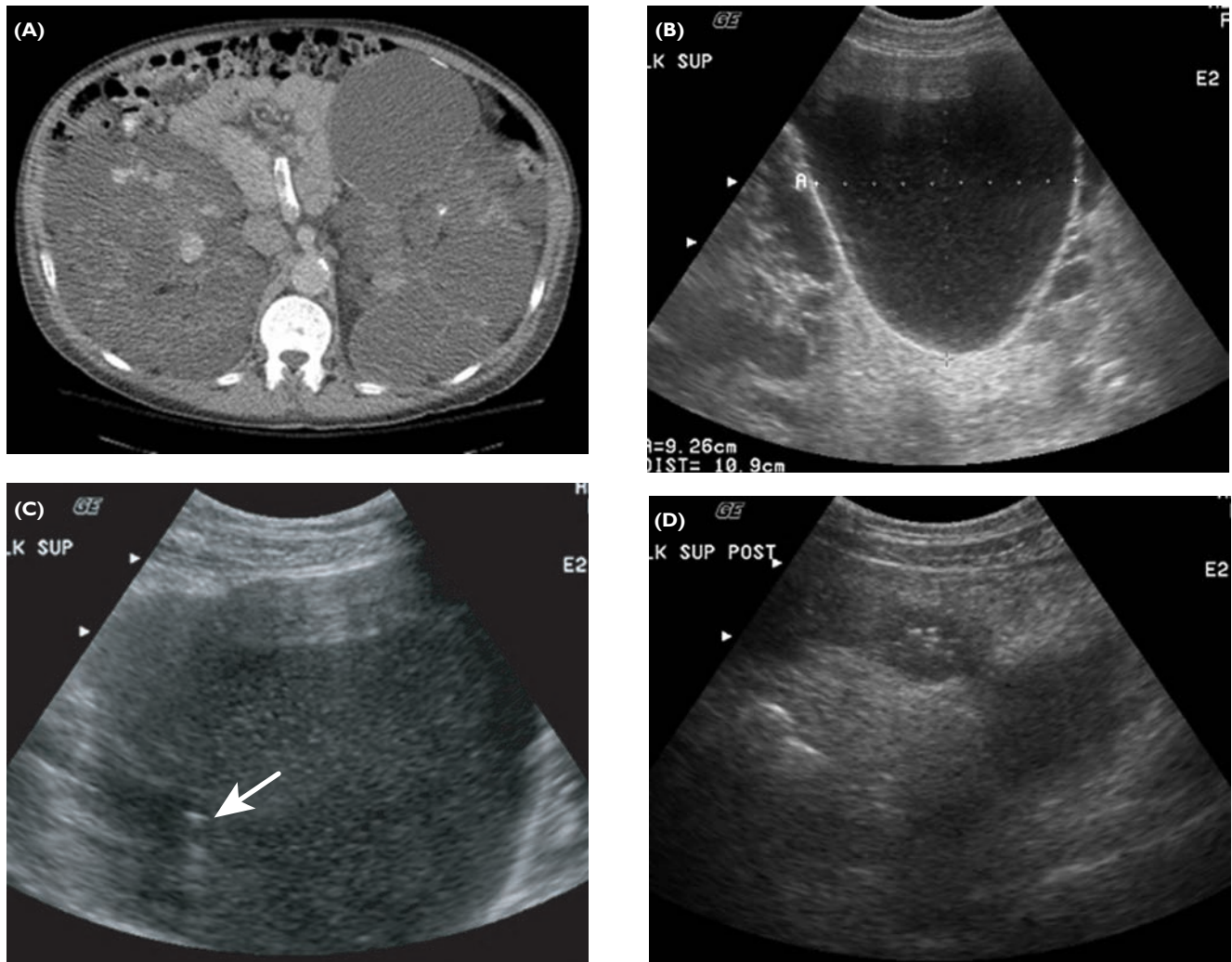


Figure 94.1 (A) Axial computed tomography (CT) image in a patient with autosomal dominant polycystic kidney disease shows bilateral multiple renal cysts. A large exophytic left renal cyst is seen which was symptomatic. (B) Ultrasound image of the cyst shows a large hypoechoic cyst. (C) Using ultrasound guidance a needle was placed in the cyst (arrow). (D) Postaspiration ultrasound shows near complete collapse of the cyst with no residual cyst.

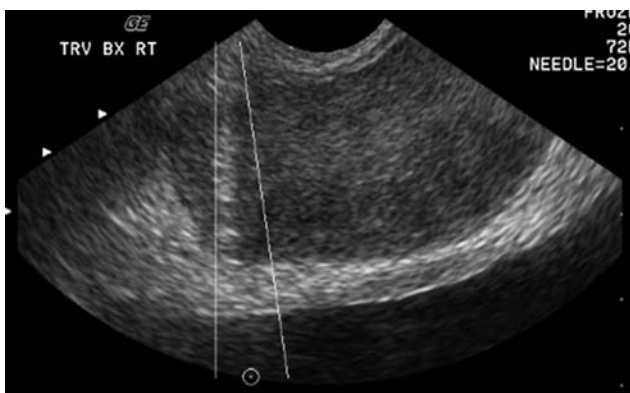


Figure 94.2 Ultrasound image of the prostate showing a needle precisely placed for biopsy.

Improvements in TRUS technology and incorporation of three-dimensional and Doppler technology into ultrasound machines have led to more accurate targeting of lesions. Color Doppler can detect subtle areas of increased neovascularity that may be seen with tumor and benign conditions such as benign prostatic hyperplasia and inflammation of the prostate. Despite advances in ultrasound technology, both gray-scale and Doppler imaging have not been able to detect prostate cancer foci with sufficient accuracy to obviate the need for random sextant biopsies.¹³ The introduction of sonographic contrast agents may show promise in enhancing tumor detection.^{14,15}

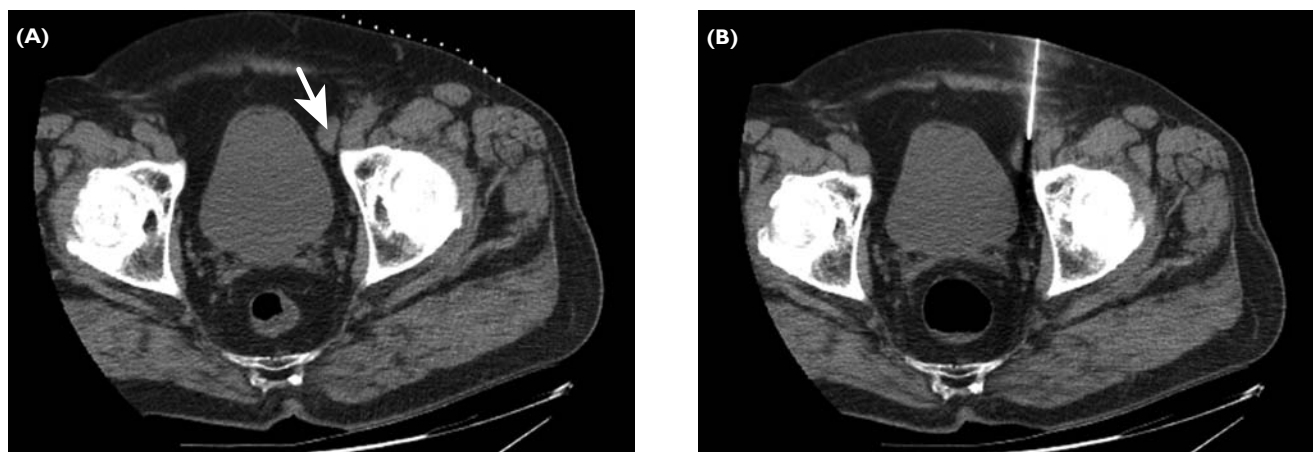


Figure 94.3 (A) Axial CT image of the pelvis shows an enlarged left external iliac lymph node in a patient with prostate cancer. Radio-opaque markers are seen on the skin which allow localization of skin entry site of the biopsy needle (arrow). (B) Using CT guidance the biopsy needle was precisely placed within the nodes avoiding adjacent vascular structures.

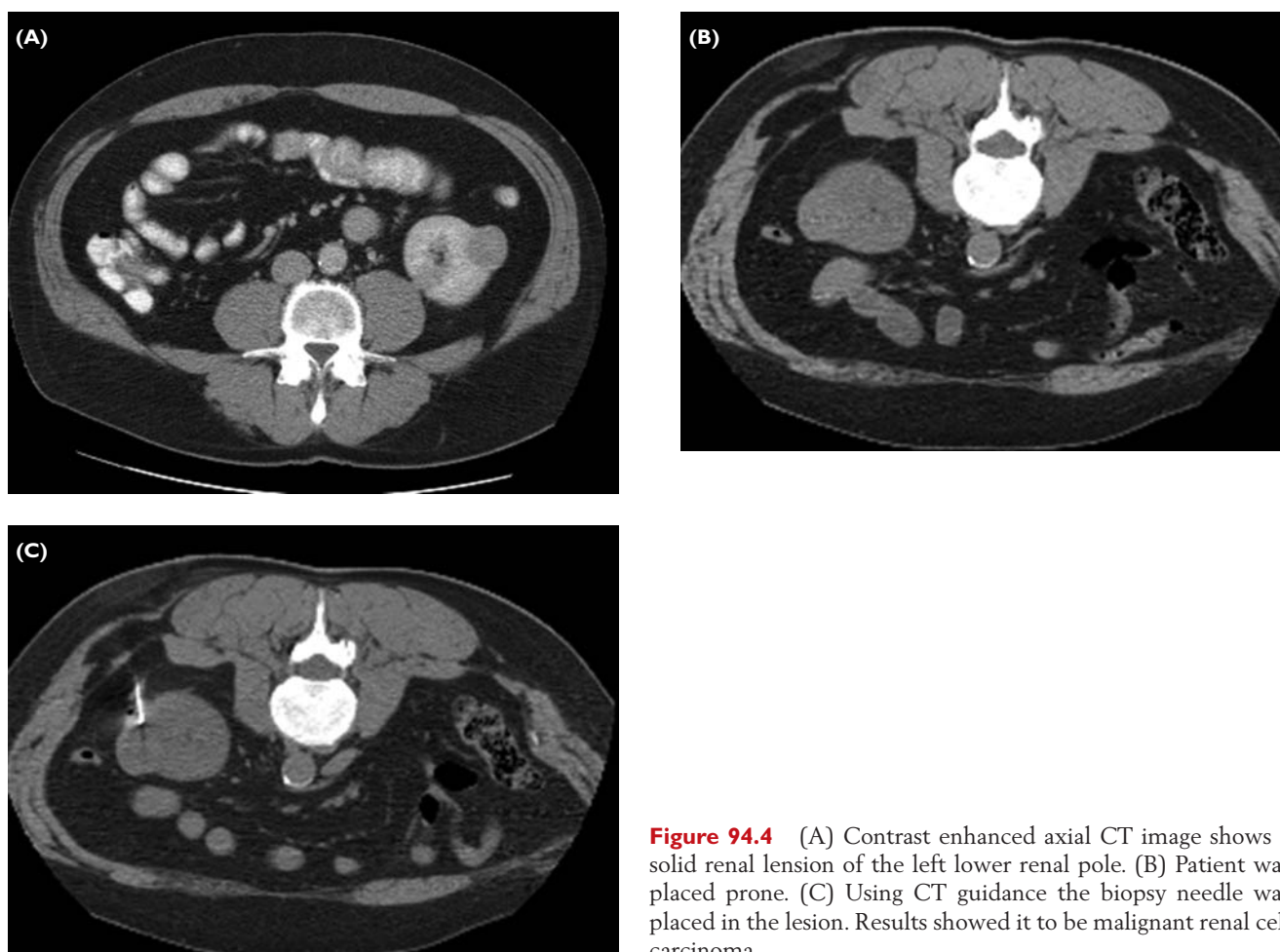


Figure 94.4 (A) Contrast enhanced axial CT image shows a solid renal lesion of the left lower renal pole. (B) Patient was placed prone. (C) Using CT guidance the biopsy needle was placed in the lesion. Results showed it to be malignant renal cell carcinoma.

Cross-sectional images provided by MRI can be used to guide prostate biopsy. Decreased signal intensity on T2-weighted images may suggest the

presence of prostate cancer. Transperineal MR-guided prostate biopsy is particularly useful in patients who have undergone total colectomy or

major rectal surgery, in whom TRUS is impossible to perform.¹⁶

MRI using an endorectal coil allows high-resolution imaging of the prostate gland. Areas of tumor appear as focal areas of decreased signal intensity against a backdrop of high signal intensity of the normal peripheral zone on T2-weighted images. Combining MR spectroscopy with routine MR examination has further improved the accuracy of prostate cancer detection.^{17–21} The technique is based on relative increase in choline/creatine and citrate ratio in areas of prostate cancer. Current MR technology precludes routine real-time spectroscopic image acquisition, which could be used to guide biopsy in the same sitting as the diagnostic examination.

Accurate detection of cancer foci through improved imaging may pave the way for a significant paradigm shift from radical treatment of prostate cancer to more focal therapy modalities.

Brachytherapy

Brachytherapy is the placement of permanent radioactive sources into or near tumor tissue. Although the technique was first described in 1913,²² it did not become popular until the incorporation of real-time ultrasound into the treatment in 1983.²³

Currently, prostate brachytherapy is performed in three steps: treatment planning, operative seed insertion, and postprocedure review and verification of appropriate location of the seeds. General or spinal anesthesia is administered and the patient is placed in the lithotomy position. Several imaging modalities have been used for monitoring brachytherapy, including TRUS, CT scan, and MRI. Iodine¹²⁵ and palladium¹⁰³ are the two common isotopes that are used for seed implantation. Postoperatively, seed localization for the final dosimetric calculation is reviewed by obtaining X-rays or a CT scan of the pelvis (Figure 94.5).

Ultrasound-guided brachytherapy

TRUS is the most popular method for image monitoring of brachytherapy. In this method pre-procedure TRUS images are used for dosimetric calculations. The same images are used in the operating room to determine location of pre-planned seed placement. Needles containing radioactive seeds are inserted through the perineum using a grid system. Sagittal and coronal images monitor the exact insertion of each needle.

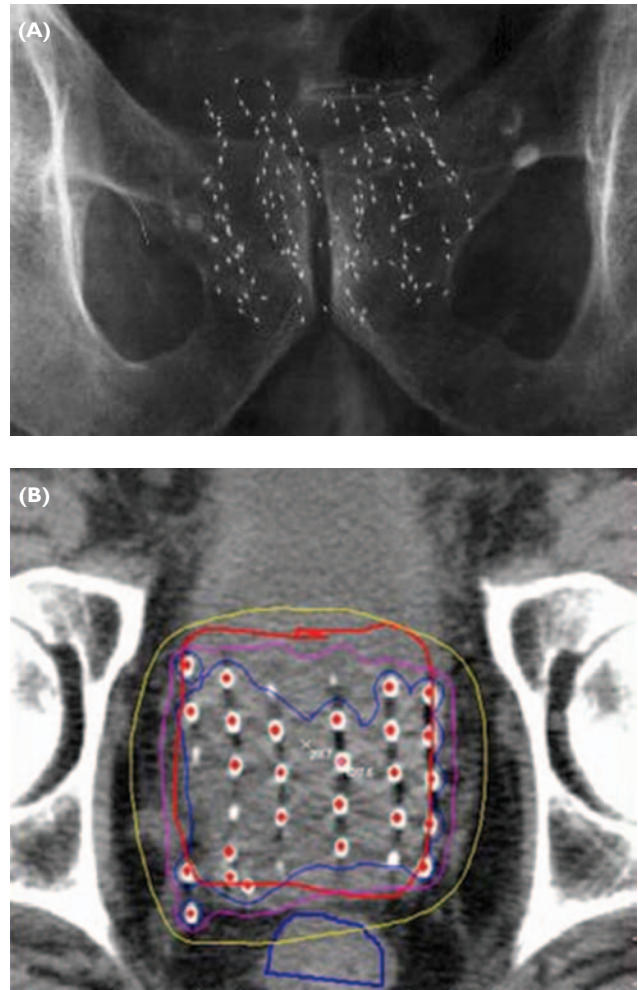


Figure 94.5 (A) Anteroposterior plain film of pelvis postseed implant. (B) Postbrachytherapy CT scan is used for dosimetric evaluation of treatment field. Courtesy of Dr Anthony Zietman, Massachusetts General Hospital.

Computed tomography-guided brachytherapy

Preoperative CT images could be used in the pre-planning step. During the treatment step, seeds could be placed under fluoroscopic guidance. CT-guided transischioirectal stereotactic brachytherapy has also been reported. It is suggested that it can be used for patients with larger prostates.²⁴ This method is not as popular as TRUS-guided brachytherapy.

Magnetic resonance-guided brachytherapy

The first MR-guided implant was performed in 1997.²⁵ In this technique real-time MRI and a real-time dose volume histogram analysis program are used. Axial, coronal, and sagittal MR images are obtained using a pelvic coil. As radionuclide seeds are inserted,

their positions are verified in real time and compared with the pre-procedure planning step. Prior to seed placement appropriate adjustments could be made to account for patient and organ movements.

Brachytherapy outcomes

In almost 25% of patients prostate specific antigen (PSA) levels increase in the first several months after brachytherapy, followed by rapid decline in the next 18 months. PSA decline may continue for 3–5 years after the procedure. Although the definition of biochemical failure after brachytherapy is still controversial, most investigators suggest that a PSA of 0.5–1 ng/ml is an acceptable end point.^{26,27} At the present time, 10-year biochemical disease-free survival ranges from 65 to 87%.^{28–30}

Brachytherapy reported complications include urinary incontinence, urethral stricture, cystitis, urinary retention, prostatitis, rectal ulceration, and urethra rectal fistula. With better patient selection and further refinements in the technique, most of these side-effects become rare events in modern prostate brachytherapy.

Erectile dysfunction depends on pretreatment potency status and the amount of radiation dose. Overall preservation of potency is reported to be between 40 and 79%.^{31–33}

Cryotherapy

Cryotherapy is the application of low temperature for tissue ablation. Prostate cryotherapy achieves a temperature of -40°C throughout the entire prostate³⁴ and for renal tumor cryoablation (Figure 94.6) temperature should reach -19.4°C or less.³⁵ Tissue injury has acute and chronic phases.³⁶ In the acute phase, low temperature causes extracellular crystal formation, intracellular pH change, damage to lipoproteins, cellular swelling, and vascular stasis. These lead to cellular dehydration, denaturation of cellular proteins, and cellular membrane disruption (Figure 94.7).

Delayed tissue injury is due to indirect cryo effects on the tissue microvasculature. Widespread thrombosis in the vascular bed leads to diminished tissue perfusion, and thus further cell death. Immunologic response to antigen release from cancer cells is also suggested to play a role in cryotherapy, although it has not been completely proven.³⁷

Cryotherapy is a fine example of the role of image-guided therapy. Early reports of cryotherapy for prostate

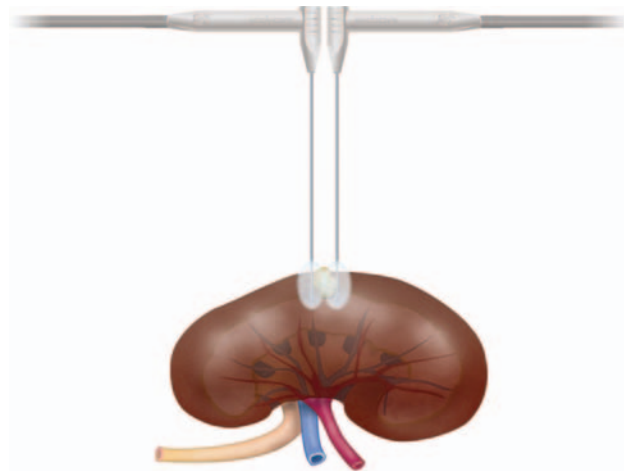


Figure 94.6 Renal tumor freeze. This illustration demonstrates the use of two 2.4 mm right-angle cryoprobes positioned on both sides of the tumor and spaced at 2.0 cm or less. The freeze encapsulates the entire tumor with lethal ice (less than -40°C). In this illustration ice balls from the cryoprobes are still forming and will eventually coalesce (typically at 10 minutes). An extra safety margin may be created by extending the ice a minimum of 1 cm beyond the tumor. Courtesy of Endocare, Inc.

cancer were associated with serious complications, including urethral sloughing, urethra-rectal fistulas, and high cancer recurrence rate.³⁸ Although the technology was promising because of minimal bleeding, relatively predictable treatment area, and overall good tolerance in patients who were not surgical candidates, inability to monitor the freezing process was found to be the major drawback.

Real-time ultrasound monitoring of the ice ball as a hyperechoic rim with acoustic shadowing revived the technology.^{39–41} The use of liquid argon or helium instead of liquid nitrogen has allowed better control over the size of the ice ball during cryotherapy.

Renal cryotherapy

Ultrasound is the most common image modality used for cryotherapy. Clear ultrasound images of the ice ball, lack of radiation exposure, and ease of use of technology make it the imaging technique of choice for most cryotherapy cases.

Because of a lack of long-term robust data, application of renal cryoablation is currently limited to small (less than 4 cm), solid-enhancing renal tumors in older patients with high operative risk (Figure 94.8). Hilar tumors, intrarenal tumors, and cystic tumors, and young age of the patient are considered relative

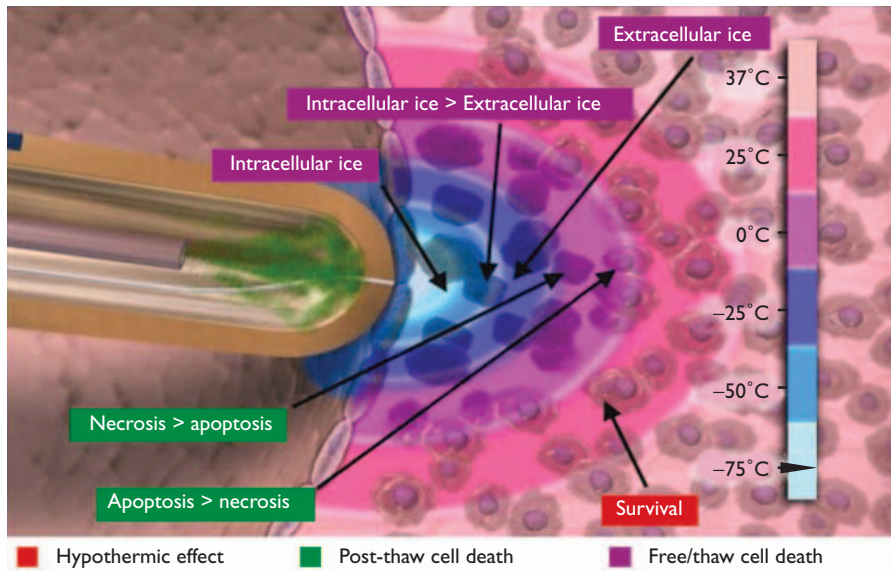


Figure 94.7 Cryotherapy principles of tissue necrosis. Formation of ice ball causes temperature gradient. Tissue necrosis or apoptosis occurs based on tissue freeze temperature. Courtesy of Endocare, Inc.

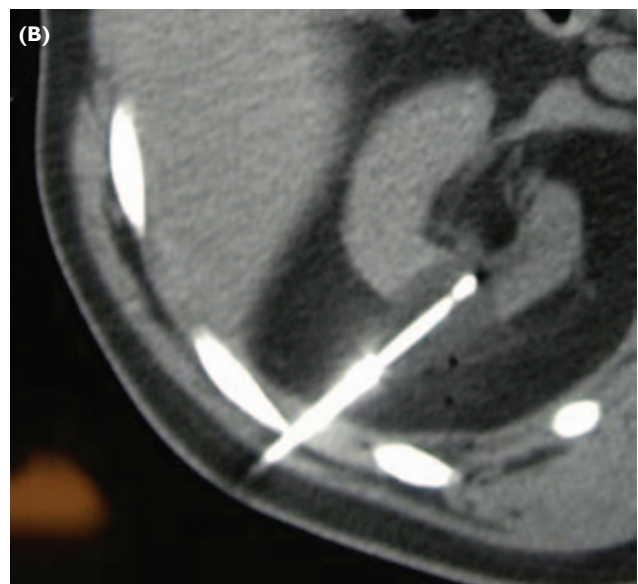
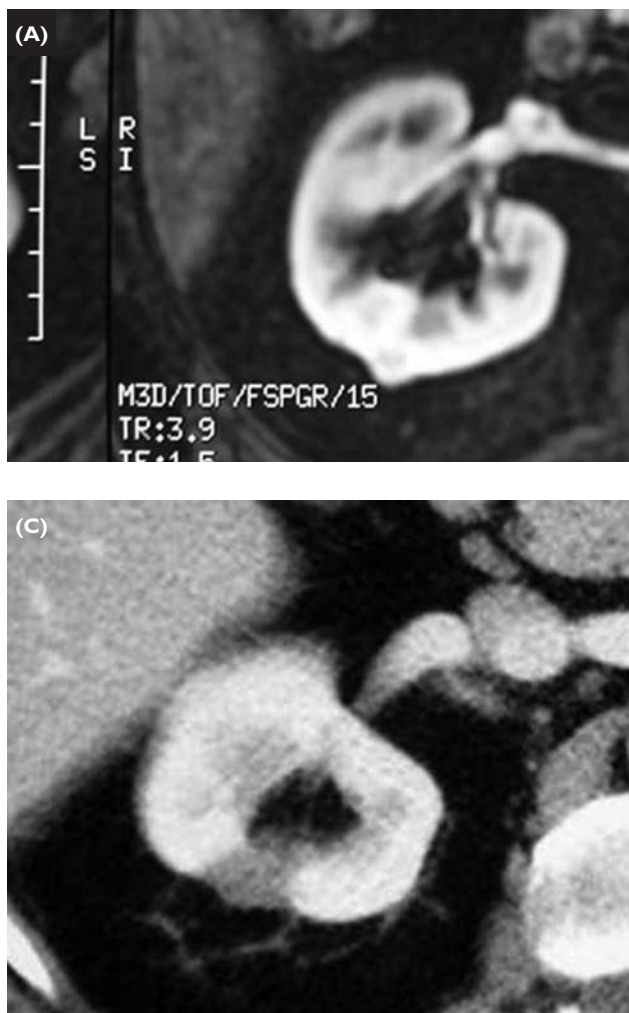


Figure 94.8 (A) A 1 cm enhancing renal mass. (B) Percutaneous cryoprobe is positioned into the tumor. (C) Six-month follow-up CT scan shows no enhancement at the site of the mass. Courtesy of Endocare, Inc.

contraindications of this technique, while irreversible or uncorrected coagulopathy is considered the only absolute contraindication.⁴²

Renal cryotherapy is described through an open, laparoscopic, or percutaneous approach.^{43,44} Percutaneous cryoablation is used more frequently with the use of

open MRI.⁴⁵ The three-dimensional images of MRI provide high-resolution images that are of incredible help in probe placement and treatment monitoring. The major drawback is that only a limited number of centers have access to open MRI. The percutaneous approach is particularly helpful for patients with small posterior or posterolateral tumors and patients with von Hippel-Lindau disease, who develop multiple renal tumors in their lifetime.

The laparoscopic approach offers the advantages of a minimally invasive approach, precise cryoprobe positioning, and monitoring of the evolving ice ball under real-time ultrasonic and direct visual control.⁴² This approach allows access to all sides of the kidney. The transperitoneal approach is commonly used for anterior and anterolateral tumors. For renal tumors located posteriorly, retroperitoneal access allows direct exposure over the tumor area and avoids any potential injury to intraperitoneal organs.^{46,47}

Renal cryotherapy outcomes

The largest reported experience with renal tumor cryotherapy so far indicates that 3-year cancer-specific survival is 98%.⁴⁸ Of 115 patients, 56 completed 3 years of follow-up. Average tumor size was 2.3 cm. Mean blood loss was 87 ml. Major complications occurred in only two patients, one with splenic hematoma and one with heart failure. Postoperative CT-guided needle biopsy at 6 months revealed residual cancer in two patients out of 115 treated patients.

Prostate cryotherapy

Prostate cryotherapy is being used as a salvage post-radiation therapy and more recently as a primary therapy in prostate cancer. Approximately one-third of early-stage prostate cancer patients undergo radiation therapy as a definitive treatment for their prostate cancer. Of those, 20–66% fail in radiation treatment.⁴⁹ It seems that between 20 and 30% of these patients have isolated local recurrence, without distant disease. Positive prostate biopsy, negative bone scan, Gleason score less than 8, and absence of clinical stage T3 or higher are used to select organ-confined prostate cancer failures. Under TRUS guidance and after insertion of urethral warming catheter, on average six cryoprobes are inserted transperineally. Third-generation cryosurgery using an argon or helium-based system with the thermocoupling, and external sphincter probe makes salvage cryotherapy more effective. Most surgeons routinely perform two freeze-thaw cycles.^{50,51} Size and expansion of the ice ball are monitored with TRUS.

Prostate cryotherapy outcomes

Because of the relatively recent reintroduction of prostate cancer cryotherapy, long-term results are not yet available. Intermediate-term (5–7 years) results are available for some second-generation machines that mainly utilize liquid nitrogen. At 5 years, disease-free rates are between 69 and 90% depending on the patient's risk factors and clinical stage prior to treatment.⁵¹ The third-generation machines use 17 gauge cryoneedles and argon gas for cryotherapy. Because of differences in methods the oncologic outcomes of the second generation may not be applicable to the third generation.

Major complications of the treatment include incontinence (4–9%), urethral sloughing, and rectal fistula (0–3.4%).^{52–54} Erectile dysfunction may occur in up to 90% of patients. Primary cryotherapy has been used as a definitive treatment for organ-confined prostate cancer. Although long-term results are not available, 5–7-year results suggest cancer control comparable to radiation therapy and radical prostatectomy. Among the side-effects, however, it seems that the impotency rate could be as high as 90% of treated patients. Because of improvements in prostate imaging with TRUS or MRI, some people advocate focal cryotherapy of the prostate in unifocal, low-volume prostate cancer patients.^{55,56}

Radiofrequency ablation

Radiofrequency ablation is achieved clinically by depositing electromagnetic energy via a monopolar needle electrode in the tissue of interest with resultant thermal injury of the target tissue. In order for the energy to be deposited, a closed loop circuit is created by placing a generator, a large dispersive electrode (grounding pad), the patient, and the needle electrode in series. The dispersive and needle electrodes are active, while the patient acts as a resistor, thereby producing an alternating electric current within the target tissue of the patient. Effective ablation requires optimized heat production and minimized heat loss within the area of ablation. For adequate tumor destruction, it is important that the entire volume of the lesion is subjected to cytotoxic temperatures. Ideal temperatures for tissue death are between 60 and 100°C.

Radiofrequency ablation of renal tumors

CT-guided radiofrequency ablation is an image-guided option for treatment of renal tumors (Figure 94.9).⁵ Currently it is used as an alternative option to conventional and laparoscopic partial surgeries in patients who

For Author to Provide

Figure 94.9 Radiofrequency ablation of an exophytic left renal lesion. Using CT guidance the radiofrequency probe was precisely placed in the lesion (placement is critical for complete treatment).

refuse surgery or have a single functioning kidney and/or compromised renal function. Based on the initial reports,⁵ renal tumor size and tumor location are key considerations in achieving complete treatment. Small exophytic tumors, 3 cm or less, provide an ideal lesion for treatment as they are surrounded by insulating perinephric fat. Intraparenchymal location is less favorable because of the vascularity of adjacent renal parenchyma, which prevents optimal heat deposition. Imaging follow-up of renal cell carcinoma treated by radiofrequency ablation and left in situ is performed with and without intravenous contrast material, consisting usually of iodinated contrast material for a diagnostic CT scan. In patients with renal insufficiency, MRI with and without gadolinium-chelate enhancement can be performed. Findings indicative of coagulation necrosis are absence of enhancement in previously enhancing tumor. This assumption is based on extrapolation from radiologic-pathologic correlation work in liver tumors.

Certain specific complications of radiofrequency ablation are postablation syndrome, injury to adjacent structures, and postprocedure pain lasting for several days.

High-intensity focused ultrasound

Intense focused ultrasound for local tissue destruction was introduced in 1944.⁵⁷ Lack of a reliable real-time imaging system, however, delayed high-intensity

focused ultrasound (HIFU) clinical applications until recent decades. Ultrasound of the target organ allows real-time monitoring of treated tissue. HIFU is currently being developed for many surgical applications as an approach requiring remote therapy of the affected organ without any incision.

HIFU causes coagulation necrosis in biologic tissues. In 1993, it was shown that it can be applied to canine prostate without any damage to the rectal wall.⁵⁸ Subsequently, it was used for the treatment of human benign and malignant prostate neoplasms.^{59,60}

To apply HIFU energy the patient is placed in the lateral position and anesthetized. Subsequently, the imaging and treatment probe is inserted into the rectum and a 2.25–3 MHz transducer is used to apply energy, while biplanar real-time ultrasound images are used to monitor the treatment.

Reported adverse effects of HIFU include urinary tract infection, incontinence, lower urinary tract symptoms, urinary incontinence, rectal burn, urethra-rectal fistula, urethral stricture, and erectile dysfunction. Urethro-rectal fistula is rare in recent published series.^{61,62}

Long-term follow-up data are scant and limited studies have analyzed the application of HIFU in early-stage prostate cancer patients.^{62–69} From all the studies presented, it is evident that this technology could treat prostate cancer, as shown by the drop in PSA and negative prostate biopsy post-HIFU therapy. At the present time no randomized controlled trials are available on cancer-specific or overall survival. Furthermore, the definition of PSA-free survival is not consistent among studies.

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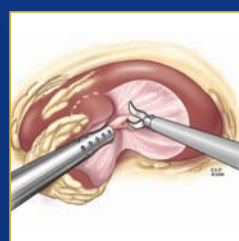
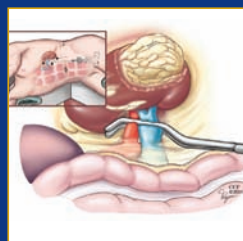
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Textbook of RECONSTRUCTIVE UROLOGIC SURGERY

Edited by

Drogo Montague
Inderbir Gill
Kenneth Angermeier
Jonathan H Ross



In recent years, although open reconstructive urologic procedures have continued to evolve and remain the main choice of urologists, newer laparoscopic and robotic approaches to reconstructive urology are becoming ever more popular and challenging the open method as the technique of choice for the urologic surgeon. The *Textbook of Reconstructive Urologic Surgery* presents a totally comprehensive approach to open, laparoscopic, endourologic, robotic, microsurgical, and prosthetic reconstructive techniques.

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